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CONTENTS.

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ON THE PHYSIOLOGY OF THE HEART OF THE SNAKE. By T. Wesley Mills, M.A., M.D., *Professor of Physiology, M'Gill University, Montreal, Canada.*

THIS paper will furnish an account of a study of the heart of the Snake, as a continuation of a series of papers already published on the cardiac physiology of the cold-blooded animals, including the Water Tortoise, the Sea-Turtle, the Fish, the Alligator, and Menobranchus.

The Snakes used belonged to the genus *Tropidonatus ;* and the experiments were made during mid-winter of 1886 and 1887. The animals had been without food since their capture in the autumn, but were not apparently in any degree hibernating, the temperature of the room in which they were kept being not far from 17° C. They were left in a tank with fresh water running constantly from a tap, but they were free either to remain in the water or to betake themselves to the dry shelves of the tank, on which they were, in fact, mostly seen coiled up together. The method of study has been that pursued throughout, viz. :— direct observation, and as a stimulus the interrupted current supplied by a Du Bois' inductorium, fed by one good-sized Daniell's cell.

The Vagus Nerve.

Comparison of the vagi throughout these experiments has established the following conclusions for this animal :—

1. In no case was either vagus without effect on the rhythm of the heart. In every case actual slowing, and with a sufficiently strong current, arrest followed stimulation.

2. In the majority of instances the *right* vagus was more efficient than the left.

3. In a very few cases both nerves seemed to be almost, if not quite, equally influential over the heart's rate.

In this comparison, then, it appears that the vagi of the Snake resemble functionally those of other cold-blooded animals examined by me.

After-Effects of Vagus Stimulation.—These were of the following kinds :—

1. Increased rate of beat, the more marked the slower the heart at the time of stimulation.

2. In all cases increased force (working power) of the heart. This was sometimes the only effect noticeable.

3. When irregularity of rhythm of either the whole or some part of the heart existed prior to stimulation, this was abolished for a longer or shorter period.

In these respects the heart of the Snake follows those of the other animals referred to above; but none of the effects have been so marked as in the case of the Chelonians, though more certain than in the Fish, so far as my own observations on that animal go.

Mode of Arrest and of Re-commencement of the Cardiac Beat.—When the current is too feeble to arrest the whole heart ; or when the whole heart is not amenable to its action, as is the case when its nutrition is much impaired, the *auricles* are the first or only parts to stop pulsating.

The *sinus venosus* is always the first part to commence to pulsate after vagus arrest, and for several beats the auricles proper may be quiescent, the wave of contraction passing over what I have called the " sinus extension," [1] to the ventricle, which may respond for some seconds prior to the auricles.

I am inclined to believe that the auricles are not a little dependent for the maintenance of their rhythm on the intra-cardiac blood-pressure, and that this may enter as one factor into the explanation of this phenomenon. At all events the same takes place in all the Poikilothermers I have examined. M'William[2] pointed it out for the Eel, and, as I indicated in my

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[1] " The Rhythm and Innervation of the Heart of the Sea-Turtle," *Jour. Anat. and Phys.*, vol. xxi.

[2] *Journal of Physiology*, vol. vi. Nos. 4 and 5.

paper on the Sea-Turtle,[1] Gaskell[2] is in error when he states that in the Tortoise an excitation wave cannot travel from the sinus to the ventricle and cause a ventricular contraction independently of a wave of contraction over both parts of the auricle.

Inexcitability of the Sinus and Auricles under Vagus Stimulation.—One of the most interesting results of the recent cardiac studies has been the unexpected demonstration that certain parts of the heart in some animals (the particular region being variable) are to a greater or less degree *inexcitable* to direct stimulation when the heart is arrested by vagus influence.

M'William[3] has stated that the excitability of the auricle is temporarily abolished in the Eel's heart under vagus stimulation. But this investigator is entirely in error when he affirms that such is not observed in the heart of the Snake, though he is correct as regards the other animals he instances.

I have established by my experiments that *during vagus stimulation the sinus and auricles of the heart of the Snake do not respond to direct stimulation.*

If the heart be at its best and the stimulating current sufficiently strong the excitability may be wholly abolished, but with a weaker current or a less vigorous heart the effect may be very partial.

I have shown that in *Menobranchus*[4] the ventricle is the part of the heart most readily and most profoundly affected by stimulation of the vagus, and that during such stimulation the *ventricle* is inexcitable.

According to M'William,[5] in the Newt the sinus, auricles, and ventricle are all inexcitable to direct stimulation during strong inhibition.

These peculiarities and differences show how dangerous it is to assume the applicability of the same physiological generalisation to animals even closely related morphologically. This conviction on my part had much to do with my beginning these

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[1] *Op. cit.*, p. 7.
[2] *Journal of Physiology*, vol. iii. Nos. 5 and 6.
[3] *Op. cit.*, p. 226.
[4] *Journal of Physiology*, vol. vii.
[5] "Proceedings of the British Physiological Society," *Journal of Physiology*, vol. vi.

studies, and continuing them on animals of related groups; for I felt satisfied that a systematic comparison would establish differences unsuspected by those accustomed to extend conclusions derived from experiments on one species or even genus of animals to others. A survey of my own series of investigations alone will amply demonstrate the desirability of such a course as I have pursued, and still more so if taken in connection with the work of other investigators, like M'William, who have followed the comparative method to any degree. A great deal of laborious work, without brilliant results, must be done, but I wish to state most emphatically my conviction that it is the only way by which a broad, solid, and safe physiology can ever be produced.

Cardiac Reflexes.

I have noticed in the Snake, as often in the Chelonians, that while the medulla oblongata is intact, the heart may be very irregular, but that upon the destruction of that part, the rhythm at once changes, becoming always regular and often more frequent. The explanation is probably to be sought in the various influences reaching the medulla, and passing down the vagi in an animal in an abnormal condition from the circumstances of the experiment. But when stimuli are applied to various parts, as the skin, the viscera, &c., the results are found to be very variable. Apparently there are great individual differences, and not a little depends on the vigour of the animal at the moment of experiment. Much of what has been established for the Chelonians[1] might be repeated for the Snake.

It only remains to note a few peculiar results of special interest in this connection. It sometimes happens in the Frog, and rarely in the Chelonians, that the first effect of vagus stimulation is not slowing but acceleration of the beat of the heart. This I have not witnessed in the Snake; but on one occasion, when reflex inhibition was unusually marked, on placing the electrodes over the lung the rate was accelerated for 3 to 4 beats. In my paper on the Fish,[2] it has been pointed

[1] *Journal of Physiology*, vol. vi.; *Jour. Anat. and Phys.*, vol. xxi.
[2] *Op. cit.*, p. 89.

out that a certain strength of current may give rise only to acceleration, or acceleration followed by slowing, when a stronger current causes only decided and prompt inhibition. In such cases the result has followed stimulation of various parts of the body. Similar observations have been made on the Sea-Turtle on stimulation of the surface of the liver.[1] In these cases the nerve mechanism requisite for reflex inhibition was intact, and the brain beyond the medulla destroyed.

As the above has been an almost constant result of excitation by the interrupted current of the anus, and above all of the tail in the Fish, it is not possible to explain it in this animal by escape of current on either the main stems or terminal branches of the vagi. Nor do I think the explanation holds for either the Sea-Turtle or the Snake. The subject has been discussed in my paper on the Alligator.[2] Our knowledge does not seem to be sufficient at present to clear up these cases fully ; in the meantime I add the results in the Snake to those already recorded for other cold-blooded animals.

In the explanation of Marshall Hall's remarkable result on crushing the stomach of the Eel, when cardiac inhibition followed, notwithstanding that the brain and spinal cord had been wholly destroyed, M'William[3] holds that Hall's explanation of inhibitory action through the sympathetic system is not valid, and that the result is to be explained by vibratory stimulation of the vagi owing to the concussion of the blow of the hammer used in crushing the stomach.

With a view of testing the above hypothesis as regards the Snake, in a case in which reflex inhibition was specially well marked, I destroyed the whole brain, and then attempted to get cardiac arrest by blows upon the animal with a large forceps, and heavy blows on the table on which the subject of the experiment rested, but with entirely *negative* results.

That in the sensitive heart of the Fish M'William's explanation might, in certain cases, be valid, it is possible to understand; but that they explain either Marshall Hall's experiment or my

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[1] *Op. cit.*, p. 7.
[2] *Jour. Anat. and Phys.*, vol. xx. p. 555 *et seq.*
[3] *Op. cit.*, p. 239.

own results, as detailed in my paper on the Alligator and the Fish, I am unable to believe.

When Hall stated his belief that the sympathetic was a channel for influences that may lessen the heart's action, he reached, I believe, a new truth.

In my paper on the Terrapin [1] I called attention for the first time to certain peculiar and hitherto unobserved phenomena, that I then felt must lead to something of importance. If Gaskell's [2] conclusions turn out correct as to the physiological character of certain different kinds of nerve fibres, then my previous statements that "the vagus is a sympathetic with inhibitory fibres, the sympathetic a vagus without these fibres, if indeed it be wholly without them, a point I have suggested previously as not yet to be considered settled," [3] may be considered the first announcement in distinct form in a published paper of a doctrine likely to be soon established on a firm anatomical and physiological basis. But yet it must be admitted that the genius of Marshall Hall was the first to penetrate the darkness. At the time of writing the above I was unaware of his suggestion as to the influence of the sympathetic over the heart.

If it be true that certain fibres running in the sympathetic system have the effect of increasing metabolic action, thus leading to exalted functional activity followed by exhaustion, then certain results of stimulation, pointed out by me in my papers on the Terrapin and the Fish, become clearer, though not perhaps fully explained, e.g., acceleration followed by slowing on stimulation of various parts of the body, even with the whole brain destroyed.

Direct Faradisation of the Heart.—The results of this method of stimulation may be stated somewhat briefly, as in the main they correspond with what I have found in the other animals experimented upon.

The results vary much with the strength of the current used, but especially with the functional condition of the heart at the time.

[1] *Journal of Physiology*, vol. vi. pp. 271, 283, &c.
[2] *Journal of Physiology*, vol. vii. No. 1.
[3] *Op. cit.*, p. 283.

When at its best the heart may be arrested on placing the electrodes upon either auricles or sinus. When somewhat exhausted, the auricles alone, or but one of them, may be arrested on placing the electrodes upon one auricle. Arrest of the sinus is, of course, always followed by stoppage of the rest of the heart.

The behaviour of the ventricle when thus directly stimulated differs from that pointed out in the heart of the Sea-Turtle.[1] In the Snake stimulation of this ventricle is never followed by that "intervermiform" action so common in the Sea-Turtle, and less frequently seen in the Terrapin. One of the first effects, if the current is not too strong, may be accelerated action, and I believe the ventricle is only arrested by the escape of current on the rest of the heart, so that the ventricular pause is really due to the arrest of the sinus, as, after arrest from vagal stimulation, the sinus and ventricle often beat for some time before the auricles begin.

The usual paralysis and light-coloured points to which allusion has been made in my other papers, are evident in the Snake, though not so marked as in the Chelonians. I see no reason to change the opinion expressed in former papers as to the meaning of these phenomena, nor to doubt that arrest of the heart on direct Faradisation is really stimulation of the fine terminals of the vagi nerves within the heart's substance.

Independent Cardiac Rhythm. — As in former instances *ligatures* have been used to separate one part of the heart from another. They are unquestionably much more reliable than clamps or other apparatus.

When the ventricle is ligatured off from the rest of the heart, in no case does an independent rhythm arise in it. Notwithstanding the great increase in pressure, the parts above continue to beat well, even more vigorously than before. A ligature between the sinus and auricles, when drawn tightly enough to prevent any wave of contraction passing down over it, completely arrests all parts below; and I have in no case seen an independent rhythm arise in these regions of the heart.

In short, my experiments have given negative results as to

[1] *Op. cit.*, 283.

a really independent rhythm, and confirm views already expressed in the other papers in which my work has been recorded.

Summary.

1. The investigations recorded in this paper were made in mid-winter on fasting but not hibernating animals.

2. Comparison of the vagi showed that in every instance both nerves were efficient; but usually the right was the most so; in some cases the difference, if actual, was minimal.

3. Stimulation of the vagi leads to after increased force and frequency of beat, or of the former only, and according to the law[1] of inverse proportion previously announced by the writer.

4. The mode of arrest of the heart is identical with that noted in the Chelonians, Fish, &c.; the same applies to the mode of recommencement.

5. During vagus arrest the *sinus* and *auricles* are inexcitable.

6. There are certain peculiar cardiac effects not explicable by reference to the vagi nerves alone, but which put the sympathetic system of nerves in a new light.

7. Direct stimulation of the heart confirms results previously noted by the writer for other cold-blooded animals. Arrest is, in all the animals of this class yet examined, owing to stimulation of the terminals of the vagi within the heart's substance.

8. As regards independent cardiac rhythm, the results have been negative.

9. The heart of the Snake, upon the whole, seems to lie physiologically between that of the Frog and of the Chelonians.

[1] *Journal of Physiology*, vol. vi. p. 281 *et seq.*

NOTE ON THE STRUCTURE AND DEVELOPMENT OF THE OVUM IN AN ANNELID (*Eudrilus*). By Frank E. Beddard, M.A., *Prosector to the Zoological Society of London, and Lecturer on Biology at Guy's Hospital.* (Plate I.)

The present paper is based upon material kindly supplied by Mr W. L. Sclater, who collected the worms during a visit to British Guiana. The general anatomy of the species (*Eudrilus sylvicola*) has been already described by me in a paper communicated to the Zoological Society,[1] where an account of the structure of the female reproductive apparatus will be found. That paper, however, contains no account of the minute structure of the ovary, which I have subsequently studied by transverse sections of the isolated gland and by teased preparations of the same. In this way I have been able to make out some facts which I believe to be new, and which therefore appear to me to be worth recording.

To the best of my knowledge the development of the germinal cells in this Annelid differs in many particulars from anything that has been placed on record in any other Annelid, and certainly differs very widely from the processes accompanying the formation of the ova in *Lumbricus*.

This latter type has been studied by many observers,[2] and has recently been the subject of a memoir [3] by Dr R. S. Bergh of Copenhagen. This paper is exclusively devoted to a description of the reproductive organs of *Lumbricus* and *Perichæta*, the greater portion referring to the former.

The ovaries (and the testes) are surrounded by a single layer of flattened peritoneal cells, which are easily to be distinguished by their structure from the enclosed mass of germinal cells.

A certain number of the latter simply increase in size and

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[1] *Proc. Zool. Soc.*, 1887, pt. ii.

[2] See especially Vejdovsky, "System und Morphologie der Oligochæten," where the structure of the ovary in several types is described and figured, and a complete list of references given.

[3] *Zeitschr. f. wiss. Zool.*, Bd. xliv. p. 303.

become ova; no changes have been observed, or at any rate have been recorded, in the remaining germinal cells, which would lead to the supposition that they aid in the formation of the ova by supplying them with nutriment. On the other hand, a single layer of cells arranges itself round each ovum, and forms a follicle from which, however, the ovum is freed when ripe and ready to fall into the perivisceral cavity; the. formation of this follicle may perhaps be connected with the nutrition of the ovum.

In certain of the Limicolæ[1] the tendency of the ovary to break up into groups of cells, each group being composed of an ovum and a number of indifferent germinal cells, may be connected with the nutrition of the ovum; it recalls the peculiar processes accompanying the development of the ovum in *Bonellia* described by Spengel,[2] and more recently by Rietsch.[3] Particularly noteworthy, from the point of view of this comparison, is the little cap of cells figured by Vejdovsky as adherent to one (pl. iv. fig. 25) pole of the ovum in *Chætogaster*, and also his figure of the ovum of *Limnodrilus* (pl. xi. fig. 2). In both cases there is also a certain resemblance to the ovum of *Eudrilus*, as will be seen from the following description:—

In *Eudrilus* the ovary, instead of being simply a mass of germinal cells enclosed in a single layer of flattened peritoneal cells, is enclosed within a definite muscular coat composed of fibres running in various directions, and accompanied by an abundant vascular supply. The muscular covering of the ovary is, as I have already pointed out,[4] continuous with the muscular walls of the oviduct; the interior of the organ is divided up by muscular trabeculæ into a number of separate compartments. So far the structure of the ovary agrees with that of *Eudrilus boyeri*, in which species I have figured the minute structure of the ovary to this extent.[5] The material which served me for that paper was not sufficiently well preserved to permit of any accurate description of the contents of the ovary, of which I am now able to give a more detailed account.

[1] Vejdovsky, *loc. cit.*, p. 145, pl. iv. fig. 25.
[2] *Mitth. a. d. Zool. Stat. z. Neapel*, Bd. i.
[3] *Recueil Zool. Suisse*, t. iii.
[4] *Proc. Zool. Soc.*, 1887, pt. ii.; *Proc. Roy. Soc. Edin.*, No. 122, 1885-6.
[5] *Proc. Roy. Soc. Edin.*, *loc. cit.*, pl. xxv. fig. 4.

All the compartments of the organ (see fig. 1) are closely packed with ova and germinal cells; in some cases (c., fig. 1) my sections showed a mass of indifferent germinal cells more or less angular from mutual pressure, and of nearly equal size, a few only being recognisable by their larger size; these latter are evidently ova in an early stage of differentiation. All the germinal cells are provided with a large nucleus, in which the nuclear substance is chiefly aggregated into a peripheral layer of spherical particles, the centre being apparently filled with a clear fluid. This statement applies to the larger as well as to the smaller germinal cells.

In other compartments of the ovary the structure was much as described above, only that the ova are much larger, and already show a delicate vitelline membrane; in a given section a considerable number of ova are frequently to be seen in a single compartment. In this stage the ova show a further differentiation in the character of the nucleus; a spherical nucleolus has made its appearance connected with the nuclear membrane by a fully developed network of nuclear substance, the interspaces being apparently occupied by fluid. Such an ovum, isolated from the ovary by teasing in glycerine, but surrounded by a mass of indifferent germinal cells, is depicted in fig. 2; fig. 1, b shows ova in the same stage of development in situ. So far the changes, as the ovum approaches maturity, only affect the ovum itself; in later stages those germinal cells which do not become ova undergo a remarkable series of changes.

These changes first of all affect the cell protoplasm; it becomes looser in texture and less readily stained by hæmatoxylin, and at the same time the outlines of the individual cells become obliterated; the nuclei retain for a certain period the characters which distinguish them in the unaltered germinal cells, and are often surrounded by a variable amount of darkly staining protoplasm, which appears to be the as yet unaltered protoplasm of the cell. A mass of germinal cells in the condition just described is illustrated in fig. 6; the protoplasm of the cells for the most part has fused into a faintly staining mass which has a somewhat fibrous appearance; here and there (a, fig. 6) a small portion of unaltered protoplasm is adherent to the periphery of the nucleus; the difference in size of the latter is perhaps to

be explained on the supposition that the larger are the nuclei of cells which have already advanced a certain distance on the way to become ova.

In later stages the nuclei of the germinal cells commence to degenerate ; this process of degeneration appears to take place in two different ways ; in some cases the nuclei become fainter and fainter, and are ultimately indistinguishable from the mass of protoplasmic material in which they are embedded ; in other cases (figs. 1, d, 8, 10), the nuclei appear to shrivel up ; such nuclei are more darkly stained by hæmatoxylin than the unaltered nuclei ; their form becomes irregular and bent in different directions, finally they become more and more compressed into a narrow thread-like body, which ends by becoming indistinguishable from the fibrous-looking mass in which the fully developed ova are embedded (figs. 8, b, 10, b).

A certain portion of the germinal cells do not, however, undergo the peculiar changes just referred to. Round the periphery of the ovum is attached (figs. 4, 5) a single layer of short columnar bodies, which have very much the appearance of the columnar follicular epithelium surrounding the bird's ovum ; except in the fact that in the Annelid these bodies appeared to be homogeneous, and to show no traces of anything comparable to a nucleus, and that they are not continuous round the entire periphery of the ovum but form a cap at one end ; they are darkly stained by hæmatoxylin, and therefore contrast with the surrounding protoplasmic mass, which, as already said, is feebly stained by that reagent. It is probable that these structures are formed out of the germinal cells, and are not a product of the activity of the ovum itself, since they appear some time after the formation of the vitelline membrane.

The probability that the layer of columnar bodies immediately in contact with the ovum is a product of the germinal cells is largely increased by the fact that in one case an ovum was closely covered at one end by a layer of germinal cells hardly at all altered in appearance ; these were darkly stained, and outside was a mass of altered germinal cells hardly stained by the colouring reagent (fig. 11).

I have already noted [1] the presence of this columnar layer

[1] *Proc. Roy. Soc. Edin.*, *loc. cit.*, p. 674.

round the ovum, but wrongly came to the conclusion that it formed a continuous layer round the whole ovum; this appearance is presented (fig. 9) by sections which pass through one pole of the ovum; an examination, however, of a continuous series has convinced me that these columnal cells only form a patch at one end of the ovum (figs. 4, 5).

The retrogression of the greater part of the germinal cells in the ovary is in all likelihood connected with the adequate nutrition of the few which become ova.

There is, however, another explanation of this phenomenon which is possible.

In the ovary of *Lumbricus* ripe ova are only found at the free extremity of the gland; the distal portion towards the point of attachment is occupied by younger germinal cells. In *Perichœta* and *Acanthodrilus* the relative position of the mature and immature ova is much the same. In all these cases the progressive ripening of the ova towards the free edge of the ovary evidently facilitates their ready expulsion from the gland when ripe.

In *Eudrilus*, on the other hand, the ripe ova are not specially found in that part of the ovarian compartments which immediately borders upon the open mouth of the oviduct; they are developed anywhere and everywhere throughout the organ; the degeneration of the remaining germinal cells and their conversion into a more or less fluid mass might therefore easily be supposed to open up the ovary for the extrusion of the ova; the muscular walls of the organ no doubt take the initiative in this process.

The conversion of a large number of the cells in the Mammalian follicle into the liquor folliculi has an analogous mechanical importance.

At the same time there is no reason to suppose that both these processes may not take place, that the product of the dissolved germinal cells may have a nutritive importance, as well as serving the purely mechanical purpose suggested above.

In the foregoing account of the minute structure of the ovary, I have not compared my description with the figures of the minute structure of the ovary of *Eudrilus* contained in Perrier's

" Recherches pour servir a l'histoire des Lombriciens,"[1] because
I am not quite certain how to interpret his figures and descrip-
tion in the light of my own observations upon material in a
much better condition for histological investigation. Perrier
figures a number of ova embedded in a granular substance, and
separated into groups of one or two by masses of fibrous sub-
stance; this latter, I presume, represents the trabeculæ which
subdivide the ovary; the granular substance probably corre-
sponds to the altered germinal cells described above.

EXPLANATION OF PLATE I.

Fig. 1. Transverse section through a portion of ovary of *Eudrilus
sylvicola* showing four compartments *a, b, c, d*; *bl.* blood-vessels.

Fig. 2. A nearly mature ovum and indifferent germinal cells from
a teased glycerine preparation.

Fig. 3. Germinal cells in different stages of growth from the same
preparation.

Fig. 4. A mature ovum embedded in the semi-fluid substance arising
from the metamorphosis of the surrounding germinal cells; at one
pole of the ovum is a single layer of cubical cells.

Fig. 5. An ovum in the same stage of development; at the upper
end of the figure is the muscular wall of the compartment; below
this are a number of germinal cells with a certain amount of unaltered
protoplasm still surrounding the nuclei, the arrangement of these and
of the protoplasmic mass below seems to indicate a flow of nutritive
matter towards the ovum.

Fig. 6. A portion of fig. 1, *d*, more highly magnified; *a*, nuclei with
surrounding unaltered protoplasm; *b*, nuclei embedded direct in the
protoplasmic mass resulting from their metamorphosis.

Fig. 7. A portion of an ovarian compartment. At one end is a
clump of unaltered germinal cells; the rest is occupied by a semi-
fluid mass, which exhibits here and there a fibrous arrangement of its
particles; *a*, embedded nuclei surrounded by a little unaltered proto-
plasm.

Fig. 8. A portion of compartment *d* in fig. 1, highly magnified to
show the degeneration of the nuclei.

Fig. 9. Section through one pole of a mature ovum.

Fig. 10. Isolated cells from compartment *d* of fig. 1; *a*, cells in
which the nuclei are unaltered, and surrounded by the remains of
the unaltered protoplasm; *b*, nuclei in process of degeneration.

Fig. 11. Cubical cells covering one pole of the mature ovum, highly
magnified and viewed from above.

[1] *Nouv. Arch. d. Mus.*, t. viii. (1872), pl. iv. fig. 76.

A VERY IMPORTANT FACTOR IN THE CAUSATION OF SOME OF THE CURVES WHICH DEVELOP IN MOLLITIES OSSIUM, RICKETS, AND OSTEITIS DEFORMANS. By W. ARBUTHNOT LANE, M.S. F.R.C.S., *Senior Demonstrator of Anatomy, Guy's Hospital, and Assistant-Surgeon to the Hospital for Sick Children.*

I BELIEVE that, in their attempts to explain the causation of the changes in form which the bones of the pelvis and lower extremities undergo in the above-mentioned diseases, surgical writers have arrived at incorrect conclusions by omitting to consider what I believe and hope to show to be the chief determining factor in their production, namely, the *acquired alteration in the position of the lumbo-sacral articulation*, which precedes and accompanies the alteration in the form of the lower extremities. The changed position of this joint, by disturbing the normal mechanism by which the body is retained in equilibrium, necessitates compensatory changes in the bones and joints of the lower extremities.

We will briefly consider some points in the mechanism of the skeleton. We are aware that the superjacent weight of the trunk, head, and upper extremities is transmitted by the fifth lumbar vertebra to the body and spinous process of the first piece of the sacrum, and by the ilio-lumbar ligament to the iliac crest.

We also know that the sacrum rotates upon the innominate bones in two directions about a transverse axis, which passes through or behind both sacro-iliac articulations, and that when the trunk is flexed upon the pelvis the sacrum rotates so that its upper portion passes downwards and forwards, and its lower extremity backwards and upwards, movement of the lower portion being opposed by the sacro-sciatic ligaments. I have shown that in this position the spinous process of the fifth lumbar vertebra transmits little or no weight to the spinous process of the sacrum, the whole of the weight being sustained by the body of the first piece of the sacrum, and that when the trunk is habitually heavily loaded while in this position the

body of the fifth lumbar vertebra may be very considerably displaced in front of its normal position.

In over-extension of the spinal column the sacrum rotates in the reverse direction about the same transverse axis, its upper portion passing upwards and backwards, and its lower extremity forwards and downwards.

The sacro-sciatic ligaments are relaxed, and this movement of rotation is opposed by the oblique fasciculi of the posterior sacro-iliac ligaments and by the remainder of the posterior sacro-iliac ligaments, which last are rendered tense by the separation of the two innominate bones by the gliding over the inclined planes of opposing elevations of the prominences on the sacral and iliac articulating surfaces.

In this position a very considerable portion of the superjacent weight is transmitted to the spinous process of the sacrum through that of the fifth lumbar vertebra, and I have demonstrated the fact that in those whose trunks are habitually heavily burdened while in this position the body of the last lumbar vertebra is displaced backwards from its normal position, and that the spinous processes of the sacrum and of the fifth lumbar vertebra are enormously hypertrophied and sclerosed.[1]

It is obvious that in some position intermediate between the positions of considerable flexion and extension of the lumbo-sacral articulation, the sacrum must be driven downwards in the direction of its vertical axis, the bone not rotating in either direction. In this position the iliac bones are separated by the increasing breadth of the descending sacrum, and the posterior sacro-iliac ligaments are therefore rendered tense, and oppose the movement of descent.

In the sedentary posture, and especially when the thighs are flexed upon the pelvis and the knees flexed or extended, as in sitting upon the floor the pelvis is rotated upon a transverse axis, so that the sacro-iliac joints are forcibly flexed, and the sacrum rotates so that its upper extremity passes downwards and forwards, and its lower extremity in the reverse direction. We may, for convenience' sake, call this movement flexion of the sacro-iliac articulation.

[1] See plate v. fig. 1, " The Physiology and Pathology of Pressure-Changes in the Trunk and Shoulder-Girdle," *Guy's Hospital Reports*, 1886.

This movement of the sacrum is illustrated very beautifully and permanently in the aged subject, since in feeble old age this bone, together with the remainder of the skeleton, undergoes changes which are of extreme interest. These I have described and analysed as regards their causation, &c., in a previous paper.[1]

It will suffice to say here, that in the old person the sacrum is the first bone in the body to alter in form from the transmission of pressure, and the earlier changes which it undergoes may be so slight as to escape observation, unless the pelvis be divided in the mesial plane, and the direction of the sacral planes and the measurement of the conjugate of the brim be carefully defined. It is probably on this account that this alteration in old age has escaped the eye of the anatomist. The obstetrician has also missed it, and apparently for the reason that this change does not develop till the child-bearing function of the individual has ceased.

In feeble old age, in the sitting posture, the flexion of the pelvis upon the lumbar spine, and therefore of the sacrum upon the iliac bones, is still further exaggerated in extreme cases by the yielding of the lower portion of the sacrum under the influence of pressure exerted upon it by the seat or couch upon which the enfeebled and aged individual spends so much time in a sedentary attitude. In consequence of the continued flexion of the sacro-iliac joints, the upper portion of the sacrum is depressed downwards and forwards, so that the concavity of its anterior surface is increased to a variable extent, and the direction of the sacral planes and the measurement of the conjugate of the brim are altered very considerably.

In most cases the sacrum yields gradually and uniformly in the position of the second sacral vertebra, but in some it yields abruptly at the junction of the first and second pieces of that bone. In a very small proportion of cases there is associated or not with this change in the form of the sacrum a displacement forwards of the body of the fifth lumbar vertebra from its normal position on the sacrum. For all practical purposes in locomotion, the condition of the lumbar spine and sacrum in an

[1] " The Causation and Pathology of the so-called disease Rheumatoid Arthritis and of Senile Changes," Trans. Path. Soc., 1886.

extreme case of forward displacement of the upper portion of the sacrum, is the same in its influence as is that of spondylolisthesis of the last lumbar vertebra. It is on account of the displacement of the lumbo-sacral articulation in a downward and forward direction that the old person in walking retains the trunk in a flexed position upon the thighs, and if an attempt is made to hold the trunk erect, the strain exerted by the ilio-femoral ligaments flexes the thighs upon the pelvis. In more advanced cases of senile change in the sacrum, the hip-joints are flexed still more extensively during locomotion, so that the knee-joints are also flexed. In such cases the subject does not retain these joints sufficiently long in this position, nor is the osseous system sufficiently feeble to allow of the long bones of the leg altering in form. The long bones of the lower extremity seem to retain their normal form during adult life in the most feeble old people. The feebly-nourished articular cartilage covering the front of the external condyle and the corresponding articular lamella on the patella not uncommonly show pressure-changes indicative of the exaggerated strain experienced by the quadriceps muscle in retaining the position of partial flexion of the knee-joint by muscular action.

What I have endeavoured to point out here is, that the displacement of the lumbo-sacral articulation forwards and down wards necessitates, when the erect posture is assumed, a rotation of the pelvis about a transverse axis in excess of that which takes place normally in vigorous adult life, and that this rotation causes flexion of the joints of the lower extremity by the strain exerted by the ilio-femoral ligaments, and that the long bones of the lower extremity are not retained for a sufficient length of time in a position of flexion, nor are they sufficiently soft for the pressure to produce change in form in their outline.

I have described the hip-joints of the decrepid old subject as being *flexed* when the erect posture is assumed. This is not accurate, because they are *really* in a condition of *extreme extension* though the thighs are *apparently* flexed upon the pelvis.

I will now refer to a fallacy that has arisen from the study of frozen sections of the human body. It has for long been known that the brim of the true pelvis is placed obliquely and not orizontally when the healthy subject is in the erect position.

By means of frozen sections, the relation of the levels of the symphysis, coccyx, &c., to one another have been defined, and it is then assumed that these levels, which have been obtained from the subject in the horizontal position, hold true also for the body when in the easy erect attitude.

The incorrectness of this assumption is easily demonstrated by standing with the back against a door, so that the heels, calves, thighs, buttocks, shoulders, and head are retained in close contact with it.

This position represents sufficiently accurately for our purpose the position of the pelvis when the body is in the supine posture.

If the door be removed after the positions of the several bony prominences have been accurately defined, and the easy erect attitude be assumed, the pelvis is felt to rotate to a considerable extent about a transverse axis, so that the plane of the pelvic brim assumes a more horizontal position, the interval between the promontory of the sacrum and hip-joints in a horizontal plane is increased, and almost the whole of the strain is thrown upon the ilio-femoral ligaments.

In the *rigid erect position*, if I might so describe the attitude the reverse of *easy*,—I mean that assumed by the soldier when standing *at attention*,—I think that the ilio-femoral ligament, in so far as it opposes over-extension of the hip-joint, has little or no share in sustaining the body in what is practically a position of incomplete extension upon the thighs, but that the trunk is fixed in this position, as regards movements of flexion and extension, by muscular action alone. In the *easy erect attitude* the ilio-femoral ligament alone, or almost alone, opposes over-extension of the hip-joint.

It is therefore obvious that the relative levels of the coccyx, symphysis, &c., differ very materially in the easy erect, the erect, and the supine positions.

In mollities ossium the sacrum and innominate bones become soft and flexible long before the femora commence to show any signs of yielding.

The sacrum yields under the influence of superjacent pressure in a manner which is similar to, but much more marked than, the ordinary senile change. The differences which exist between the two conditions are easily explained.

In the mallacic subject the sacrum is very much softer than in feeble old age; therefore, in the sedentary position, its lower portion yields much more completely and abruptly, so that the obliquity of the pelvis is materially altered and the direction of the force applied to the first piece of the sacrum changed,— the upper portion of the sacrum being compressed in its length, and the tendency to the forward displacement of the promontory being less than in ordinary feeble old age.

Again, in the erect position, the strain exerted by the ilio-femoral ligaments in over-extension of the hip-joints, instead of producing an apparent flexion of these joints upon the pelvis, causes the soft innominate bone to yield by the inward and upward pressure of the head of the femur. This general yielding of the innominate bones is exaggerated by the development of what are apparently ununited fractures in the pubic and ischial rami. These I have shown[1] to be not ununited fractures, but *local exaggerations produced by strain of the general process of decalcification,* and that associated with this decalcification there is an endosteal and periosteal deposit of lamellæ of fibrous tissue containing no lime salts; in fact, of a decalcified callus. The whole process results in the formation of an amphiarthrodial joint in the continuity of what was originally firm bone. On account of this yielding of the innominate bones while the subject is in the erect position, the pelvis rotates much more extensively upon a transverse axis than it does in the healthy subject, or even in feeble old age, and on this account the direction in which pressure is trans-mitted to the sacrum is less forwards and downwards, being more directly downwards in the vertical axis of the bone.

These reasons quite explain the differences which exist between the old and the mallacic sacra. At the same time it is obvious that no abrupt and sudden distinction can be made between the two forms, in the same way that it is practically impossible to separate, by a sharply drawn line, senile changes and senile mollities ossium.

I have asserted above that the force exerted by the head of the femur is directed upwards and inwards, and not chiefly

[1] "Partial Mollities, Rheumatoid Arthritis, and Charcot's Disease," *Trans. Path. Soc.,* 1885.

upwards, as in the vigorous adult, as she walks with unburdened trunk. The explanation of this is, that the feeble mallacic subject, as she walks, does not retain the thigh upon which she is standing at the time in a position of partial adduction, but by rotating the trunk and pelvis about an antero-posterior axis she balances the pelvis upon the femur in an abducted position.

Obstetric writers seem to forget this difference between the directions in which force is transmitted to the head of the femur in the feeble mallacic subject and in the vigorous adult. In the latter, during locomotion, the pelvis rotates hardly, if at all, about an antero-posterior axis. I hope to discuss this at length in a subsequent paper.

We will now pass on to the consideration of similar changes in rickets.

If we examine a rickety child, who has not commenced to walk, sitting upon the floor or bed, with its back well bent and its head well forwards, as it leans forward to play with its toys or to assume a position of rest, we see that the spinal column presents a long single antero-posterior curve, which is frequently much exaggerated in the lower dorsal and upper lumbar regions, this particular excurvation being commonly called "rickety spine."

It is quite obvious that this curved column, weighted by the head and upper extremities, must exert upon the upper portion of the sacrum a considerable pressure in a forward and downward direction, tending to increase the curvature of the sacrum and to approximate the promontory and symphysis.

In rickets, as in old age, mollities ossium and osteitis deformans, the sacrum is relatively softer than any other bone in the body, and it yields more readily to pressure. This is well observed if the body of a child such as I have described be examined. The promontory of the sacrum is seen to be displaced forwards, and but slightly downwards, and in most cases the sacrum does not suffer much compression change in its own axis.

At this stage a lateral curve may develop in the lumbar region, and subsequent to the appearance of this curve a lateral dorsal curve is observed, this being obviously compensatory to that first developed.

In this case, as the child has never walked, it is absurd to suggest that the lateral curve which was first formed was dependent upon the child standing upon one leg, or upon its carrying loads in its arms or hands. I think that the mode of development of many of these lateral curves is much more simple than is usually supposed, and in considering it I will not limit myself to the rickety subject alone, since the cause is the same in both the rickety and the non-rickety.

I will briefly relate the circumstance which led me to my conclusion.

I was much interested in a child who was suffering from great muscular weakness of the dorsal muscles following an attack of chorea. This was so extreme that she was at first quite unable to sit up. I examined her spine carefully on several occasions, in order to eliminate any possibility of disease, and found it perfectly normal.

As the child gradually regained her strength, she used to sit up in bed and play with her toys. After she had been sitting for several hours in this position, I examined her spine one evening, and found a well-marked lumbar curve with its convexity to the left, and a distinct lateral curve in the dorsal region. I caused her to be placed on her back without a pillow for two days, and on again examining her I found no sign of the lateral curves which I had observed.

After a few days she was again allowed to spend several hours in the sedentary position, and on examining her in the evening, I found the lateral curves were present, but not quite so well marked as on the previous occasion. Having satisfied my curiosity as to the manner in which the curves developed, I took precautions that she should not be again liable to their recurrence.

I have since observed the development of similar curves in feeble children under analogous circumstances, but have never seen them develop so rapidly as in the case I have just described.

We are well aware that in the young subject, as compared with the adult, the fibro-cartilages are very thick, elastic, succulent, and compressible, and that the proportion borne by the fibro-cartilage to the bone is much greater in the lumbar and

lowest dorsal regions than in the remainder of the dorsal portion of the column.

While the child is occupying the sedentary position, its spine is flexed so as to form a long single curve.

The anterior portions of the elastic fibro-cartilages are much compressed, and as they are thicker in the lumbar region there is more tendency for the fibro-cartilage to recoil in that region than higher up.

If the sitting position be assumed for long, in very feeble children especially the body is very soon flexed to one side, and in almost every case it is the right side towards which the child bends for rest. This is probably owing to the fact that the child usually bends to that side when using its right arm and hand to play with its toys, &c.; and it will be observed that in older children, and in the adult, when sitting and resting, the trunk is flexed to the right. This lateral flexion liberates the greater portion of the compressed fibro-cartilage, whose right margin is now alone compressed, and owing to the recovery by the fibro-cartilages of much of their original bulk the lumbar spine, with the last one or two dorsal vertebræ, forms a lateral curve, whose convexity is directed to the left. The dorsal curve is formed subsequently to the lumbar curve, and is compensatory or consequent upon it.

This explanation of the mode of development of many cases of lateral curvature applies to the sedentary position in all feeble subjects; and it is quite obvious that the permanent lateral curves in the lumbar and dorsal regions are merely the *retention by the spinal column of what is a transitory normal attitude*, in exactly the same way that the dorsal excurvation which develops during growing life, and all the changes in the form of the spinal column which are the results of carrying loads in various ways, are one and all retained exaggerations of normal physiological attitudes.

Three factors seem to be necessary in order that such a more or less permanent lateral curve be developed. They are:—

1. A feeble muscular and consequently a feeble osseous system in a young growing subject.

2. The formation of a long single curve by the assumption of the sedentary position for a considerable time.

these depending on the extent of the abduction of the foot. The knees are separated by an interval whose extent varies directly with the degree of flexion of the knee-joints and with the size of the angle which exists between the inner margins of the feet. This is an extremely important physiological point in the development of the bowed-legs in rickets, and in osteitis deformans, and it is one which is readily demonstrated on the healthy subject. The legs form two curves in two planes. In the transverse plane the convexity is outwards, and in the antero-posterior plane forwards. It is obvious that much of the delay in walking, which is so common in rickety children, is due to this considerable interference with the normal mechanism of locomotion. Instead of the ligaments performing a great portion of the adjustment of the equilibrium at the knee-joints, the whole strain is thrown upon the flexor and extensor muscles.

In consequence of the abnormal position assumed by the lower extremities, the long bones yield in the two planes. It is obvious that if the femur and tibia retained their normal form, the amount of muscular exertion which would be required to retain the narrow portions of the condyles in position upon the tibia would be simply enormous, and the joint would also be extremely unsteady, and but of little use.

This difficulty is overcome by the bowing of the long bones, so that the lower aspect of the condyles of the femur come into accurate contact with the upper surface of the tibia, and this is assisted by an absence of the normal rotundity of the condyles, which for purposes of steadiness become flatter and broader than usual. It is by this means that the knee-joint may be retained fixed by the exercise of a relatively small amount of exertion.

Owing to the formation of the lateral curves in the femur and tibia, the strain, which is exerted usually by the patella upon the front of the external condyle during flexion, is in the bowed-leg transferred to the front of the internal condyle. The opposing articular surfaces of internal condyle and patella increase in area, while the anterior portion of the outer condyle and the corresponding patellar aspect atrophy in the same proportion. In a well-marked case the patella articulates with the internal condyle alone, both patella and condyle

presenting well-marked curvation, lipping, and other pressure changes.

The opposing aspects of the inner condyle and tibia present much more marked pressure-changes than do the outer condyle and the opposing tibial facets, and the cause of the difference is quite obvious from a mechanical point of view.

Having analysed the causation of the rickety condition, we will now pass on to examine the similar changes which ensue in osteitis deformans. In that disease, as in rickets and old age, the sacrum yields before any bone in the body, and to a varying extent in each case.

In osteitis deformans we have a heavy head flexed upon the trunk, with a marked flexion change in the cervical and upper dorsal regions of the spinal column. In order to walk, the trunk or displaced head is displaced backwards to such an extent that pressure is transmitted to the sacrum in the vertical axis of the upper portion of that bone, and there is little tendency to forward displacement of the promontory.

The sacrum alters in form in such a manner that the interval between the lumbo-sacral articulation and promontory in a horizontal plane is increased. On consideration the mode of production will be quite obvious. Having accounted for the displacement of the lumbo-sacral joint, it is also apparent that you must get, resulting from the excessive rotation of the pelvis about a transverse axis, a great strain upon the ilio-femoral ligaments and an over-extension of the hip-joints. This over-extension of the hip-joints necessitates an attitude of flexion of the knee-joints, both in standing and in walking, as well as an altered position of the ankle-joints. As a consequence of this flexion you get strain in two planes, but chiefly in the antero-posterior, and the long bones yield along them under the influence of the superjacent pressure. The opposing articular surfaces of the hip and knee-joints undergo slight but definite alteration in form, in order to accommodate themselves as much as possible to the altered mechanical condition. I might go into an infinite amount of detail concerning the changes in the conditions I have referred to, but I think I have discussed it sufficiently *to show that many of the alterations in the form of the pelvis and of the attitude and form of the*

bones of the lower extremity are due to the yielding of the sacrum in advance of the other bones of the skeleton, and the consequent displacement of the lumbo-sacral articulation.

Since writing this paper I have, in a contribution[1] to the ensuing number of the *Guy's Hospital Reports,* 1887, elaborated these principles, which I fear I have put forward rather crudely in the preceding paper, with regard to the factors which determine the formation of the varieties of rickety knock-knee and bow-legs, and I have explained fully the mechanical circumstances which produce the variations in character existing between simple static and rachitic knock-knee. The subject is one of great importance and interest.

[1] "On the Causation of the Deformities which Develop in Young Life."

A CRITICAL STUDY IN CRANIAL MORPHOLOGY. By J. BLAND SUTTON, F.R.C.S., *Lecturer on Comparative Anatomy, Middlesex Hospital, Hunterian Professor, Royal College of Surgeons, England.*

ANATOMISTS, as a rule, apply the term intra-cranial to any structure lying within the bony framework of the skull. Practically this may be the most useful definition of the term, but exception must be taken to it on morphological grounds.

We know that, in the course of development, the human skull passes through a membranous stage, then the base chondrifies. Later we have membrane bones superadded to the cartilaginous skull, finally the cartilage is replaced, and the skull, for the most part, represented by bone.

If we wish to compare the disposition and relation of arteries and nerves in the various types of skulls, the comparison is best effected when the skull is in its embryonic condition. Suppose we choose the human skull when it is fully chondrified, and examine the course of the various nerves, we shall be much surprised and interested at the simplicity of their courses.

In order to study the relations of nerves to the chondral skull, a foetus should be chosen between the third and fourth months. After the skin has been removed and the head soaked for some hours in running water, the various bones preformed in membrane, such as the squamosals, parietals, frontals, nasals, &c., can easily be removed without damage to the underlying cartilage.

A long series of dissections, conducted in this manner, shows clearly enough that the cranial nerves and their branches follow fairly direct courses; and the intricate paths followed by many of the nerves in the adult skull is entirely due to the modifications induced by the addition of osseous material, and the remarkable changes which occur in the branchial apparatus, the result of the transformation of an aquatic into a terrestrial animal.

The nerves most affected in this metamorphosis are the fifth, seventh, and tenth. With these three nerves our attention will be chiefly occupied.

These nerves agree in one or two important particulars, but differ in others, whilst a comparison of the points of agreement and difference leads to a conclusion of some importance.

The three nerves are in agreement, inasmuch as they develop on their main trunk, soon after quitting the brain, a ganglion; but there is considerable variety regarding the position of this ganglion. In the adult skull the ganglion of the vagus lies outside the bony skull, that of the facial is enclosed in the petrous bone, whilst the Gasserian ganglion is lodged in a compartment of dura mater, known as the cave of Meckel.

The course of the vagus, from its ganglion onward, is purely extra-cranial, but the facial traverses the curious Fallopian canal, to emerge at the stylo-mastoid foramen, whilst the subsequent course of the fifth is even more labyrinthine.

On examining the trunk of the facial nerve in a fœtus at birth, we shall be astonished to find, on removing the dura mater from the periotic bone, that the geniculate ganglion, with its petrosal branches, is exposed to view in a recess, which later becomes roofed over by a thin plate of bone. The obvious deduction from this is that the remainder of the course of the facial nerve is extra-cranial, and this is further supported by the fact that in the chondral skull the facial lies on the inner wall of the tympanum, merely covered by membrane.

In connection with this part of the question relating to the facial nerve, Gegenbaur's paper, "Bemerkungen über den Canalis Fallopii," in the *Morphologische Jahrbuch*, Bd. 11, 1876, should be consulted.

When we come to deal with the fifth nerve, we find the ganglion entirely closed in by dura mater; but the nerve enters this cave by a very distinct opening at the apex of the periotic bone.

A careful examination of these conditions led me to propound the view, that morphologically the true cranium is limited by the dura mater, and that any structure quitting the brain becomes extra-cranial at the spot where it perforates the dura mater. If this be so, then the Gasserian ganglion and its branches, including the nasal nerve, the structures in the cavernous sinus, the geniculate ganglion of the seventh with its petrosal nerves, the tympanic branch of the ninth and tenth

nerves, the internal carotid artery, from the anterior clinoid process downwards, and the meningeal vessels, must all be for the morphologist extra-cranial.

If it be admitted that structures situated between the dura mater and the osseous walls of the skulls are morphologically extra-cranial, then there can be no difficulty in dealing with the distribution of the nerves between the place where they quit the basal foramina and the spot where they emerge from the secondary osseous passages, such, for example, as the stylo-mastoid and infra-orbital foramina, the inferior dental canal, &c.

If we accept this view, then the subsequent portion of my labour becomes easy, for the intricate pathways of the distal portions of these nerves must be regarded as a species of entanglement due to increased growth of the brain, and the consequent encroachment of the cranial cavity on the face; the modification of the appendicular elements of the skull, and the addition of membrane bones.

In order to render the matter clearly, let me take each nerve-foramen in the skull-base in order. The result will be to show that when a nerve passes through an osseous opening it passes between two or more bones, or between two or more centres of ossification.

The French anatomist Serres drew attention to this in 1819, but at that time the exceptions were very numerous. Now, I shall endeavour to show that only one foramen is obdurate, viz., the foramen rotundum.

1. *Optic.*—This foramen marks the confluence of the orbito- and pre-sphenoid centres.
2. *Sphenoidal Fissure.*—This results from the confluence of the orbito-, ali- and pre-sphenoid, completed externally by the frontal.
3. *Ovale.*—This at birth is a notch in the posterior border of the ali-sphenoid, converted into a foramen by the periotic capsule.
4. *Auditory.*—This foramen marks the line of confluence of the pro-otic and opisthotic centres.
5. *Jugular.*—This is formed by the basi- and ex-occipital completed externally by the periotic capsule.

6. *Ant. Condyloid.*—This is a notch in the ex-occipital, but is converted into a foramen by the basi-occipital.

7. *The Foramen Magnum* is bounded by four distinct centres, squamo- basi- and the two ex-occipitals (fig. 1).

Fig. 1.—The mode of formation of the foramina in the base of the skull. The shaded parts represent the primitive cartilage. *E*, ethmoid; *P*, pre-sphenoid; *O*, orbito-sphenoid; *A*, ali- and *B*, basi-sphenoid; *P*, pro-otic; *Op*, opisthotic; *Pt*, pterotic; *O'O''O'''*, the occipital nuclei. The numbers 1–8 refer to foramina in the following order:— Optic, Sph. Fissure, Rotundum, Ovale, Auditory, Jugular, Ant. Condyloid, Magnum. *M*, the mastoid foramen. The figure 5 is on the periotic capsule.

The foramina considered in the foregoing section may be regarded as the true apertures of exit for the cranial nerves; the remainder are perhaps best looked upon as adventitious, in that they are the direct result of the addition of osseous elements to the primitive cartilage cranium. Their mode of formation fully bears out the relation previously mentioned, that nerve-foramina mark the confluence of independent ossific centres, or lie between distinct bones. Each will be separately considered.

The anterior ethmoid foramen, transmitting the nasal branch

of the ophthalmic division of the fifth, occupies the suture be-
tween the os planum and the frontal bone. The slit beside the
crista galli, which transmits this nerve to the nasal fossa, is
formed by the lateral and mes-ethmoid centres.

The holes in the malar bone, for the passage of the malar
branches of the second division of the fifth, are situated in the
line of confluence of the three nuclei for this bone.[1] The infra-
orbital canal marks the line of confluence of the malar and
maxillary centres, whilst the naso-palatine nerves pass through
minute canals, formed by the confluence of the pre-maxillary
bones of opposite sides. The posterior palatine canal is a space
between the pterygoid plates of the sphenoid, the palate, and
superior maxillary bones. The spheno-palatine, as *its name im-
plies*, is a notch in the palatine bone, completed by the sphenoid.
The temporal branch of the fifth nerve emerges from the orbit
by way of the suture between the malar and ali-sphenoid; and
the pterygo-palatine, is formed by the root of the internal
pterygoid plate and the sphenoid process of the palate bone.

To my mind, the most instructive of all the cranial nerve-
foramina are those resulting from the transformation of the
branchial arches; in order, therefore, to render this part of the
matter clear, the disposition of the nerves in a dog-fish and in
a human chondro-cranium are compared in the accompanying
drawings (figs. 2 and 3).

In the case of the dog-fish the essential parts are the palato-
quadrate bar, which is suspended from the skull by ligaments,
and the hyomandibular cartilage. This supports the Meckelian
cartilage; posterior to it is the hyoid arch, followed by the series
of branchial bars (fig. 2).

In the human chondro-cranium we find three bars represented,
the anterior, which is the equivalent of the palato-quadrate of
the shark; Meckel's cartilage; and the hyoid bar. No branchial
arches behind this are developed, except the distal end of the
thyroid.

A glance at the two drawings, with the nerves diagrammati-

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[1] In the discussion which followed the reading of this paper, Professors
Macalister and Thane admitted the existence of two nuclei for this bone, but
regarded the third as occasional or rudimentary. Even if this be so, it does not
invalidate the principle urged here. Observations on the ossification of the
facial bones are very difficult.

cally represented in relation, is sufficient to render the fundamental agreement obvious. The nerves chiefly concerned are part of the fifth, the seventh, ninth, and tenth; and the student of human anatomy knows full well that it is precisely these
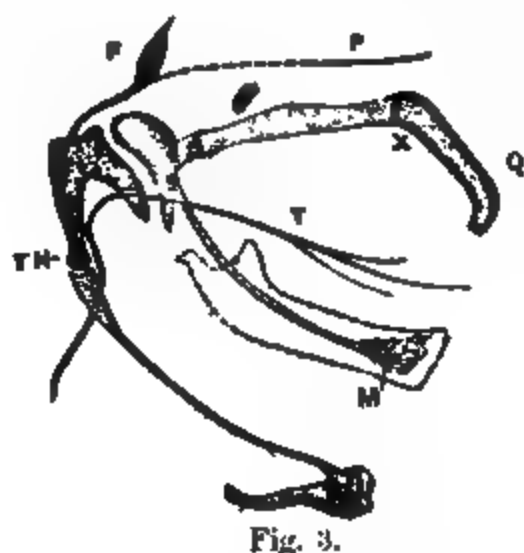
Fig. 2.

Fig. 3.

Fig. 4.

FIG. 2.—The appendicular elements of the skull of a dog-fish, showing the relation of the facial nerve.

FIG. 3.—The same parts in the human chondro-cranium.

FIG. 4.—The mode by which the Vidian canal is formed.

Q., palato-quadrate bar; *M.*, Meckel's cartilage; *H.*, hyoid bar; *T.H.*, tympano-hyal; *Hy.*, hyomandibular; *F.*, facial; *P.*, palatine (Vidian) nerve; *T.*, chorda tympani; *V.*, Vidian canal.

nerves which run complicated courses, and emit their branches in such apparently extraordinary situations. The precise homology of the various branches in the two forms is of little importance in the present argument, and will not be insisted upon, but the general plan of the nerves is in striking accordance.[1]

The details of the modifications in the relations of the nerves

[1] I have not ventured to encumber this paper with a detailed account of the metamorphosis of the palato-quadrate, Meckelian, and hyoid bars in man. Those interested in this will find an account of it in my little work on "Ligaments."

in the chondral and osseous conditions of the human skull may be given as follows :—

The Fifth Nerve.—Of the various branches of this nerve, which in the adult pursue complicated courses, few follow so extraordinary a course as the nasal branch. In the osseous skull it enters the orbit by way of the sphenoidal fissure, and quits it through the anterior ethmoidal foramen. The nerve re-enters the skull, but lies outside the dura mater, and gains the nasal fossa by way of the slit beside the crista galli, and lies between the nasal bones and the mucous membrane covering it. In the chondral skull its course is almost as direct as in the dog-fish. The complication arises in this method: the ossification of the frontal and the nasal bones separates it from the integument, so that in early life the nerve pursues its course between bone and cartilage; gradually the pressure of the nasal bone brings about absorption of the underlying cartilage, so that eventually the nerve lies between bone and mucous membrane. The expansion of the cerebrum leads the frontal bone to encroach upon and overlap the ethmoidal region, and thus buries the nasal nerve in the process. The conclusion is obvious: from the time this nerve passes the sphenoidal fissure, although it re-enters the bony cranium, its course is strictly extra-cranial. The osseous labyrinth which hides the second division of the fifth results from the addition to the chondral skull of the superior maxilla, and need not further detain us, as the facts speak for themselves.

The construction of the Vidian canal presents much that is interesting. The first suspicion that the great superficial nerve (Vidian) is of morphological importance suggested itself to my mind upon observing its relatively large size in the embryo as compared with its insignificance in the adult. Elsewhere I have endeavoured to show that the internal pterygoid plate is an adventitious element of the skull, inasmuch as it is an ossification of the anterior (ventral) end of the Eustachian cartilage, which, on its detachment from the parent cartilage, fosters itself on the sphenoid. The mode of construction of the canal is after this fashion: the internal pterygoid plate fuses at first with the ali-sphenoid; when the latter joins the lingulum the pterygoid also anchyloses with it. The coalescence of these three elements

with each other leaves a chink, as represented in fig. 4. The effect of this is to bury the Vidian nerve, which up to this period passed, as shown in fig. 3, freely above the bar. That portion of the nerve which intervenes between the geniculate ganglion and the canal, like the small superficial petrosal, is within the bony cranium, but outside the dura mater, hence it is, strictly speaking, extra-cranial.

The same line of argument applies to the inferior dental nerve. In the chondral skull its course is simplicity itself; but when the ossific nuclei for the lower jaw invest the Meckelian cartilage, the coalescence of six' ossific nuclei disguises its original simple path.

The Facial Nerve.—So long as the branchial bars retained their original function in any degree, the course of this nerve is in conformity with the remaining branchial nerves; but on the transformation of the proximal portion of the hyomandibular cleft into a tympanum, profound modifications ensued. The extent of this modification is clearly indicated by the fact that in the chrondral stage of man's skull the nerve lies in a groove on the outer wall of the periotic cartilage, and the chorda tympani flits between the hyoidean and mandibular bar. In the adult skull the complex course of both nerves is too well known to need description. It may be mentioned, however, that the stylo-mastoid foramen is bounded by three ossific nuclei; they are the epiotic, tympanic annulus, and the tympano-hyal. The " iter chordæ anterius " is a chink between the squamosal and the tympanic elements of the temporal bone.

In the same way may we account for the otherwise perplexing passages of the tympanic branches of the glossopharyngeal and vagus nerves. In the cartilaginous periotic capsule these nerves pursue the simplest possible courses; but when they become hidden by the tympanic bone, and embedded among the intrinsic ossification of the otic capsule, complexity displaces simplicity.

An impartial survey of the facts, which have been stated in the foregoing pages, is sufficient to show that the almost endless complication which characterises the mammalian skull must be a direct result of the evolution of the highest skull from a simpler form. The two chief factors in producing complexity

are the gradual increasing volume of the brain, especially of
the cerebrum, and the suppression of the branchial apparatus.

At first the cerebrum lies in the same horizontal plane as the
primary vesicle; in time it is seen to rotate backwards, and, in
the higher types, overlaps dorsally, anteriorly, and laterally the
underlying vesicles. The increase in size ruptures the vault of
the chondro-cranium, so that it is covered by membrane. To
gain space, the enlarging cerebrum invades the facial portion of
the skull and appropriates the ethmoidal region. Laterally it
dips among the branchial appendages, and claims part of their
territory. Hence the Gasserian ganglion and its branches, the
nerves in the cavernous sinus, and the geniculate ganglion, with
its petrosal ramifications, are drawn into the space between the
dura mater and the middle fossa of the skull.

The opinion that the dura mater should be regarded as the
limit of the primitive cranium has a pathological value as well
as an anatomical import, for it serves to explain, what on other
grounds would be inexplicable, the occurrence of dermoid cysts
lying in the folds of the dura mater. If we remember that the
integument and dura mater are actually in contact in many
situations, at that period of life when formative energy is at its
height, the mystery vanishes. The discussion, however, of this
part of the question is foreign to the purpose of the paper.

It must have struck many, in studying the arteries, that the
external carotid distributes itself exclusively to the exterior of
the head and neck, if we except the meningeal branches. It
is a remarkable fact that the arteries which supply the dura
mater are, with one exception (the branch from the vertebral)
derived from the external carotid; and it is very significant
they are all distributed to the outer aspect of this membrane,
and lie between it and the bony framework. Morphology
cannot derive much evidence from arteries; nevertheless, when
cautiously cross-questioned, facts of value may in some case be
elicitedfrom them. I think it is so in the present instance.

Concluding Remarks.—It affords me peculiar pleasure to
find that in the views expressed in this paper I do not stand
alone. As has already been mentioned, Gegenbaur, in 1876,
drew attention to the fact that the course of the facial nerve,
from the hiatus outwards, is extra-cranial. My earliest views

on this matter were published in July 1883 in the *Journal of Anatomy and Physiology*, vol. xviii., in a paper " On the Ossification of the Temporal Bones," and full attention was drawn to the reasons for regarding the dura mater as the limit of the true cranium. Some further observations were published in the same *Journal* (October 1883) in connection with the anatomy of the chimpanzee, chiefly in regard to the nerve-foramina. In March 1884 Dr Albrecht, in a communication to the Sociétié d'Anatomie Pathologique de Bruxelles, *Sur les Spondylocentres épipituitaires du Crane*, has put forward an opinion that the ali-sphenoid is to be regarded as a facial bone, and that the space between the petrous bone and the orbito-sphenoid (practically the middle fossa) is extra-cranial. Finally, he states that all structures outside the dura mater are extra-cranial; but unfortunately, the general conception is disguised under the complexity of a new, and, to my mind, unnecessary terminology. In this paper I have simply extended, by the introduction of additional evidence, the views enunciated briefly in 1883.

THE DEVELOPMENT AND TRANSITION OF THE TESTIS, NORMAL AND ABNORMAL. By C. B. LOCKWOOD, F.R.C.S., *Hunterian Professor of Comparative Anatomy and Physiology, Royal College of Surgeons of England.* (PLATE II.)

LECTURE II.

Glomeruli of Wolffian Body.

THE glomeruli of the Wolffian body have been frequently referred to in the first Lecture, but, so far, nothing has been said concerning their histology or development. This omission may now be repaired, and, fortunately, suitable human embryos are available for the purpose. This happens because the glomeruli have just appeared in the youngest human embryo at my disposal, and are still in their most primitive condition. In order of development the glomeruli are not manifest until after the Wolffian duct and tubules are well established; and, roughly speaking, their appearance coincides with the ·earliest budding of the limbs; but, preparatory to their development the Wolffian tubules grow and alter. It may be best to glance for a moment at that phenomenon, and then proceed with the development of the glomeruli.

In Lecture I. the development of the Wolffian tubules was traced until they looked as if they were hollow outgrowths from the duct, and in this early stage their length was insignificant, and they only reached from the inner side of the duct as far as the peritoneal epithelium. But afterwards the tubule elongates, and, by the time the glomerulus has appeared, is slightly bent. A typical tubule would consist of the following parts:—(1) a section carrying the peritoneal opening, and known as the peritoneal funnel,[1] (2) a dilated vesicle into which this opens, (3) a coiled tubulus proceeding from (2), and terminating in (4) a wider

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[1] Foster and Balfour, 2nd edit. p. 193.

portion opening into the Wolffian duct.[1] Evidence has been adduced to show that the human embryo, as well as the rabbit, has at the fore end of its Wolffian body peritoneal openings or nephrostomata, but these will not be mentioned again, because this portion of the organ totally disappears, and has nothing whatever to do with the events which follow. But the tubules do not present, either in the rabbit or in the human embryo, any peculiarity at their opening into the Wolffian duct; but towards its other extremity there is a dilatation, into which a bunch of capillaries grows to form a glomerulus. It therefore follows that all the human embryo ultimately possesses of the four divisions of a typical tubule is (1) a coiled canal and (2) its dilated glomerulus-containing part. But we must not forget that in one of the transverse sections of a human embryo of the thirtieth day of intrauterine life a very strong resemblance to the typical arrangement can be traced (fig. 19, Pl. XV. Lecture I.). In this case the tubule running from the peritoneal epithelium and ending at a large glomerulus is of the greatest significance, and seems to represent a "peritoneal funnel." Before describing the development of the glomeruli, the manner of growth of the tubule calls for inquiry, and at the outset ,it is clear that it can hardly take place by additions made at either end. As far as can be judged, the cells which form its walls divide and multiply, and in so doing increase both the length and calibre of the canal they surround.

Taking both the pronephros and mesonephros into consideration, two sorts of glomeruli may be developed in connection with them. The first variety are called external glomeruli, because they protrude into the pleuro-peritoneal cavity instead of into the tubules. Their presence is undoubted in the chick, but it is very questionable whether they exist in the rabbit, and in man their development has hardly been established, although I have described a specimen in which it is possible that they have been imitated. However, in the absence of confirmatory evidence, it would be rash to aver their existence upon such grounds as these, and therefore, under the circumstances, only

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[1] Since the first lecture was published, I have seen an exceedingly wide opening between a Wolffian tubule and the pleuro-peritoneal cavity in a rabbit's embryo of 9 days and 18 hours.

the other kind of glomeruli remain for examination. In contra-
distinction to those which have just been mentioned these are
named "internal glomeruli," and they protrude into the Wolffian
tubules. A perusal of Mr Sedgwick's[1] monograph shows that
the distinction is rather one of detail than of principle, because
that author satisfactorily shows that the external glomeruli
are simply internal glomeruli which have protruded into the
peritoneal cavity through greatly widened-out nephrostomata.
However, the names are very convenient, and deserve to be
retained. In future, for reasons which have just been given,
only internal glomeruli are in question. The accompanying
figure, made from a section of a human embryo at about the
thirtieth day, affords an idea of the appearance of one of these
structures shortly after its appearance. The canal of the Wolffian
tubule is at this time about $\frac{1}{600}$th of an inch in diameter, but
is dilated at the end which is furthest from the Wolffian duct to
contain the glomerulus. The latter consists of capillaries sur-
rounded by round mesoblastic cells (Pl. II. fig. 23), and
covered, where it protrudes into the tubules, by a reflection
of the lining epithelium, which consists of a single layer
of cubical cells. In this specimen there is no histological
difference between the cells which line the tubule, and its
dilatation, and those which cover the glomerulus. At this early
stage the glomerulus bulges prominently into the expanded
tubule, and is continuous by a wide base with the rest of the
mesoblast of the Wolffian body. However, a trace of a con-
striction has begun to form at the base, and this by its
increase will afterwards form the " neck of the glomerulus."
The mesoblast, which in a great measure composes the Wolffian
body and glomeruli, is embryonic in type and consists of round
nucleated cells, which are about $\frac{1}{1500}$th of an inch in diameter.
These elements have indistinct margins, and in some parts
protoplasmic processes unite adjoining cells. The blood-vessels
of the Wolffian body at this stage are not very numerous, and
are bounded by spindle-shaped cells; they run as loops into
the glomeruli (fig. 23). Whatever histological changes take
place after this, and they are many, the anatomical arrangement

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[1] Adam Sedgwick, *On Early Development of the Anterior Part of the Wolffian
Duct and Body in the Chick*, &c., p. 24.

which has been described, a glomerulus protruding into the dilatation of a tubule, does not alter, except that the glomerulus, owing to a narrowing of its neck, becomes more pendent into the cavity which contains it (figs. 24 and 25). As regards the place at which the glomerulus protrudes into the tubule, it may be noted that the invagination is not exactly at the end of the tubule, but usually at one side. Of course such a trivial circumstance as this hardly alters the anatomical arrangement.

After it has been established in this way, the glomerulus grows larger, and the tissues of which it is made assume new and altered characters. For instance, both in human embryos and in rabbits, the epithelium which covers its surface changes its cubical shape and becomes flattened. The cell nuclei do not participate in the change but remain round and plump, and bulge in a striking manner and clearly mark the margin of the glomerulus (fig. 25). The layer of epithelium which lines the interior of the glomerulus-containing sac, that which corresponds to Bowman's capsule in the kidney, also becomes flattened, except where it joins the cubical epithelium of the tubule; here it retains its original form (fig. 24). Accompanying these changes in the epithelium are others in the substance of the glomerulus. It has been seen that at its first appearance the latter consisted of small round cells, a few of which were elongated and bounded the capillary loop. The human embryo which yielded this information was somewhere near the thirtieth day of intrauterine life and had but a slight degree of perfection. In another human embryo, ⅝ths of an inch long and about the seventh week of intrauterine life (fig. 24, also fig. 39, p. 61), and in which the limbs and fingers and toes were clearly formed, the development of the glomeruli had advanced a step. During the early phases the epithelial covering was easy to recognise because of its cubical shape and deep staining, but in the seven weeks' embryo its identity is by no means so clear, although, without doubt, it is represented by some slightly flattened cells which cover the surface. Moreover, the elements which form the bulk of the glomerulus are bigger than they were at the thirtieth day, and this seems due to an increase in the amount of the protoplasm which surrounds the nucleus. But, besides increasing in amount, it is perceptible that the protoplasm, especially that

which belongs to the cells near the neck of the glomerulus, has sent out branches which, by joining with corresponding processes from other cells, are beginning to form a reticulated network; this reticulum is of the greatest interest and importance, and will be mentioned again presently. However, the bulk of the glomerulus consists at this stage of rounded nucleated cells interpenetrated by a few capillaries, which seem to originate as follows:—Along certain routes the embryonic cells, both of the glomerulus and of the Wolffian body in general, elongate and arrange themselves in parallel lines, separated by a narrow interval into which blood from the neighbouring great vessel enters. Nothing could be simpler than this process, and after originating like this the vessels consist of an afferent set, running from the aorta to the glomerulus, and an efferent set, opening into the great vein of the Wolffian body, the posterior cardinal vein.

If such a glomerulus as that which has been described be compared with those of the kidney, with which every one is familiar, their want of perfection is manifest. We are therefore impelled to carry our inquiries further, and a human embryo whose body and head together measured $1\frac{3}{16}$ inch long, and which had arrived somewhere near the tenth week of intrauterine life (fig. 40, p. 65), afforded a suitable opportunity. In this embryo some of the glomeruli were as large as, if not larger than, those of the adult kidney, and their vascularity was remarkable (fig. 25). The whole glomerulus is composed of a complicated interlacement of tortuous capillaries, amongst which a few cells are intermingled; and, moreover, the epithelial elements have deviated from their early cubical shape, so that both the surface of the glomerulus and the interior of its capsule are lined with flattened nucleated cells. By the time the glomeruli of the Wolffian body have reached this stage of development their resemblance to their fellows of the kidney is very obvious and needs no comment. However, the comparison has an additional interest, because it enables us to infer that the Wolffian glomerulus has reached the period of its greatest perfection. It will be shown presently that this is a stage at which few glomeruli are destined to arrive. Many of those which appear during the earliest and greatest development of the Wolffian body participate in the

atrophy which overtakes the foremost part of the organ, but this is a point which may be reserved for a little while.

Whilst the glomeruli have been passing through these phases of development the tubules and matrix have not remained quiescent. But, before speaking of these, it is important and interesting to ascertain how many tubules and glomeruli the human embryo may possess. Of course an exact determination is hardly possible, but in longitudinal sections of the youngest human embryo that has been mentioned in these pages (fig. 1, p. 637), and which was estimated to have arrived at the twenty-third day of intrauterine life, I calculate that from fifteen to sixteen tubules, and a like number of glomeruli, were present. In the longitudinal sections of another human embryo, also spoken of before, and estimated to have arrived somewhere near the thirtieth day (Pl. XV. figs. 21 and 22, Lect. I.), there seemed to be from eighteen to twenty tubules and glomeruli. The difference in these two cases is so small that it is evident that, assuming the ages are right, an inconsiderable, or possibly no new development of extra tubules or glomeruli takes place between the twentieth and the thirtieth day of intrauterine life. In a third human embryo which has been mentioned already (p. 39), and which was estimated to have reached nearly the seventh week of intrauterine life, it is hard to say whether the number of glomeruli and tubules has increased; although, on the contrary, some of the foremost, as will be described hereafter, have begun to atrophy (fig. 39, p. 61). The same holds good for a larger human embryo, previously mentioned (fig. 40, p. 65), and whose length was $1\frac{3}{16}$ inch, and whose age was thought to be about the tenth week of intrauterine life; in this specimen there is no increase in the numbers of the glomeruli, but a greater perfection of some, and an atrophy of others. If these inferences are correct, it is clear that they establish a difference between the human embryo and that of the chick, for in the latter, as Foster and Balfour [1] point out,

"In addition to the primary tubules, secondary and tertiary tubules are formed on the dorsal side of the primary tubules. They are differentiated out of the mesoblast of the intermediate cell mass and open independently into the Wolffian duct."

[1] Foster and Balfour, 2nd edit., p. 192.

Judging from the number of openings into the Wolffian duct, it seems exceedingly doubtful whether in the human embryo any tubules are developed after those which have been described.

It follows, therefore, from what has gone before, that in the human embryo the glomeruli of the Wolffian body reach perfection at a comparatively early period, probably about the tenth week of intrauterine life, but even then some of those which are anterior have begun to atrophy, and it may be said in anticipation that this is the ultimate destiny of all of these structures. But before this interesting topic is touched, if the natural consequence of events is kept in view, other circumstances claim attention, and foremost may be mentioned the relative positions of the various structures which compose the Wolffian body. The situation of the duct, tubule, and glomerulus are portrayed in fig. 2, Lect. I. p. 638, which represents a human embryo at about the twenty-eighth day, or in fig. 37, p. 48, which represents the Wolffian body and genital mass, or sexual eminence as the latter is sometimes called, of a rabbit of thirteen and a half days of intrauterine life. These drawings clearly show that the duct lies towards the extreme outer limit of the organ, that is to say, as far as possible away from the mesentery and aorta; the glomerulus, on the other hand, lies more towards the inner side and in front, so that it is quite near the base of the mesentery. It therefore follows that the duct and glomerulus are some distance apart, and this interval is occupied by the tortuous tubules. That part of the Wolffian body which is nearest the spine contains, as was said before, the vein (posterior cardinal) which carries away its effluent blood. It is desirable to make a careful note of these relations, because they help the interpretation of many subsequent events. A word may be said in this place concerning the lining epithelium of the various canals. In rabbits and in human embryos the Wolffian duct is lined with columnar ciliated epithelium during the later stages. The Wolffian tubules have also a lining of regularly arranged columnar cells, and the inner edge of the cells (fig. 37, p. 48) has large and irregular protoplasmic protrusions. After the seventeenth day in rabbits the cell lining of the tubules of the Wolffian body becomes less

columnar and particularly like the epithelium which lines the convoluted tubules of the kidney.

Parenchyma of Wolffian Body.

The only portions of the Wolffian body which have not been particularly mentioned are its epithelial covering and the mesoblast which surrounds and imbeds the other elements. The latter has already been mentioned indirectly in connection with the connective tissue portion of the glomeruli, so that it is natural to complete the account of its development. Doubtless it is unnecessary to begin anew the description of the mesoblast which composes the human Wolffian body. At first it consists of round protoplasmic cells, each of which possesses a central nucleus. The process by which a very definite reticulated stroma is developed from the round nucleated cells is quite simple; their protoplasm sends out branches which unite with those of adjoining cells so that at last a nucleated meshwork is established. The various stages by which these alterations are brought about are shown in the accompanying figures (figs. 23, 24, and 25), which also indicate that, besides forming the reticulum, some of the cells are converted, in the manner which has been described, into the walls of the various capillaries and blood-vessels. Mere pictorial representations convey but a poor idea of the perfection and beauty of the tissue which forms the parenchyma of the Wolffian body, nor does comparison afford much assistance. Its resemblance to the so-called mucoid or gelatinous connective tissue,[1] so far as the meshwork is concerned, is palpable; but here the likeness ends. To complete the analogy it would be necessary to demonstrate the presence of mucin in the meshwork, and it is hard to tell how this could be accomplished. But, whatever the nature of the parenchyma of the Wolffian body may be, the tissue which constitutes it is not solely confined to that organ. The last embryo which has been described, that which was supposed to have attained the tenth week of intrauterine life, possesses kidneys of some perfection, and the various glomeruli and tubules which go to form the organ lie in an identical matrix. This observation is so much in accord-

[1] *Vide* Klein, *Atlas of Histology*, 1880, p. 88.

ance with the views usually entertained of the relationship which exists between the permanent kidneys and Wolffian bodies, that there is no difficulty in its acceptance; but in a little while it will be demonstrated, that by the time it has reached a certain stage of development, the body of the testis has a reticulum which differs in no material degree from the parenchyma of the organs which have just been mentioned, namely, of the kidney and of the Wolffian body. The importance of this statement, both from a developmental and from a pathological point of view, will be admitted when we consider that branch of our subject which treats of the development of the body of the testis, and the time has now arrived at which this task may be profitably and conveniently undertaken.

Development of the Body of the Testis.

The mere origin of the body of the testis is a matter of general agreement. This point has been clearly determined in the chick and in many of the smaller mammals, and therefore, so far as they are concerned, the question does not call for lengthened notice. Under the circumstances it is proposed, as a preliminary, to endeavour to ascertain how the gland appears in rabbits and afterwards in human embryos. When once the *origin* of the testicle has been illustrated the development of its various constituents will call for attention, and upon this branch of the subject the widest differences of opinion exist. It would be easy to verify this statement by reference to the well-known writings of Foster, Allen Thomson, or Balfour, or to the admirable epitome which Janošik gives in his recent memoir. As we proceed, the different views will be indicated, but at present let us confine ourselves to the question of the origin of the body of the testicle. At present it is a matter of common acceptation that, at their commencement, no one can discriminate between the rudiments of the ovary and those of the testicle, for I am not aware that Waldeyer's views upon this point have met with acceptance.[1] That author thinks that in chicks a thick germinal epithelium is indicative of female sex, whilst in males it is thin.[2] Therefore, although at last these

[1] *Eierstock und Ei*, pp. 133 and 135.   [2] *Ibid.*, p. 137.

glands differ so widely, yet at first they originate from a cell mass which is identical for the male or female; and which in its early stages betrays no evidence of its ultimate fate, whether destined to become an ovary or a testicle. Under these circumstances a suitable name has to be found for this indifferent rudiment, and it is usually called the sexual eminence. The sexual eminence of the rabbit's embryo may be clearly seen during the thirteenth day of intrauterine life. Before describing the manner of its appearance it is desirable, for reasons stated before, viz., the general untrustworthiness of time reckonings, to try to give an idea of the perfection of these embryos. Therefore, it may be said that the head and trunk together, although still curved upon each other, may be estimated to be about two centimetres long. The fore and hind limbs have incipient flexures; as yet they are deficient in digits, but the latter are already foreshadowed by dark parallel lines in the somewhat spatulate ends of the limbs. Finally, the head and face are well formed, and the eye has a well-marked lens and choroid. The internal organs—the heart, lungs, liver, and intestines—are noticeable objects, but the permanent kidneys have not appeared. A transverse section through the middle of the abdomen of such a rabbit's embryo, that is to say, one of thirteen and a half days (fig. 37, p. 48), shows that the Wolffian bodies are large and elaborate organs. The enlargement is in a great measure due to an increase in the growth of the tubules, which, besides having a larger calibre, are more tortuous; moreover, it is obvious that the gland has larger glomeruli and is more vascular. The length of the Wolffian body is still very great compared with that of the embryo. It reaches from the diaphragm, which by this time has almost completed its development, nearly as far as the hind end of the peritoneal sac; in fact, it stretches nearly the whole length of the back of the abdominal cavity. In the specimen from which the drawing was made (fig. 37, p. 48) it happens that the genital eminence is already prominent, and consists of a collection of cells which are heaped up towards the front and inner side of the urogenital ridge, and very near the place where the latter abuts upon the base of the mesentery. At this time the bulk of the urogenital ridge consists of the Wolffian body and its various

constituents. The relation of the genital eminence to the uro-
genital ridge may be illustrated by saying that, if the length of
the ridge be divided into thirds, the genital mass would occupy
rather more than the middle third.[1] This is only an approxi-
mate estimate, because the eminence tapers at either end, and
therefore it is hard to determine its exact limits.[2]

The histology of the genital eminence in its earliest stages is

Mes

FIG. 37.—Wolffian body and sexual eminence of rabbit, 13½ days. *W.D.*, Wolffian
duct; *C.V.*, cardiac vein; *Mes.*, mesentery; *A.O.*, aorta; *G.M.*, genital mass.

of great interest and importance.   In order to see the appear-
ances which are described below, sections of extreme thinness
are essential, and a high power, such as Zeiss, $\frac{1}{12}$th oil
immersion, should be used. If the section should happen to be
at all thick, or the power low, the genital eminence looks like a
homogeneous mass of cells. However, it consists of two sorts of

[1] These remarks are also applicable to rats, corresponding in their development
to thirteen days' rabbits.

[2] Foster and Balfour, *loc. cit.*, p. 221, say that at its first commencement in the
chick the genital eminence extends the whole length of the Wolffian body and
genital ridge, but subsequently is restricted to its anterior part. See also
Waldeyer, p. 136, who makes a similar statement.

elements, viz., of a stroma of large branched anastomosing cells, and of unbranched cells (fig. 26), contained in the meshes of the stroma. The relative proportions of branched and of unbranched elements is not the same throughout. Where the eminence abuts upon the Wolffian body the network of branched cells predominates, and is very easy to see. It is continuous with the stroma of the Wolffian body, and the description which has been given to the latter applies to it in nearly every particular. The protoplasm of the branched cells is here and there collected into masses of some size, and where this happens large granular oval nuclei, which have one or more nucleoli, are usually seen (fig. 26). As the cells of the stroma approach the peritoneal surface of the genital eminence they, and their nuclei, become a little smaller, and there is a corresponding diminution in the size of their meshes. At the same time the stroma cells stain more deeply, and their nuclei are irregular in outline. In this and other specimens (fig. 32) some of the processes of the stroma are prolonged between the cells of the germinal epithelium as far as its peritoneal surface. As the genital eminence nears the Wolffian body its stroma becomes more palpable, but near the germinal epithelium it is partially obscured by a number of unbranched cell elements, whose nature is to be determined by an examination of the germinal epithelium. It is convenient to do this by simply tracing the lining epithelium of the abdominal cavity over the genital eminence (fig. 26). It has been said before that the peritoneal epithelium, at the thirteenth day, consists of a single layer of more or less cubical epithelial cells. Supposing that we look at this investment as it reaches the edge of the genital eminence, it may be seen that the individual cells have undergone considerable alteration. First of all, their size is no longer uniform, some being large and oval, others columnar, and not a few quite small and insignificant. So far as size is concerned, a very simple explanation is at hand, for a very active process of multiplication by fission is going on, and the smallest cells are simply those which have just been formed (fig. 26). But, returning again to the margin of the genital eminence and tracing the peritoneal epithelium over it, a marked alteration in the disposition of the epithelium is to be observed. Instead

of being arranged in an uniform layer their depth varies, and their deep surface has an irregularly festooned appearance. This appearance is caused by some of the cells of the germinal epithelium invading the stroma. These cells are recognisable because they stain more deeply than the larger oval cells which belong to the stroma, and because they have no protoplasmic branches. Whether the meshes of the stroma contain any other unbranched cells except these is hard to decide, but, after a great deal of study, I think that if thin 'sections are examined this question will be answered in the negative. It is exceedingly hard to give an adequate idea of this tissue either by description or by delineation, and although I think it is possible, even from early stages, to recognise the germinal cells, yet it is to be feared that only a very inadequate impression of their peculiarities has been conveyed.

It is obvious that the preceding account does not apply to the very earliest beginning of the genital eminence. But before attempting that topic, a few spindle-shaped cells near the base of the genital eminence (fig. 37, p. 48) may be mentioned. They merely bound blood-vessels which, even at the thirteenth day, have entered the base of the eminence; and they belong to the stroma.

Further knowledge of the genital eminence may be gained from younger embryos, and is confirmatory of the preceding. However, this part of the subject is so important that perhaps it may be well to introduce it here, more especially as by so doing the study of the human embryo is facilitated. In a rabbit's embryo at the beginning of the thirteenth day, and in which the limbs were merely short protrusions, the lining of the peritoneal sac consisted of a layer of cubical cells, each containing a nucleus. These cubical cells were continued over the urogenital ridge without exhibiting any alteration except towards its inner aspect. In this situation, the spot which the genital eminence afterwards occupies, the cells are slightly more columnar (fig. 27) and lie at least three cells deep. Although the various structures, such as tubules and glomeruli, contained in this rabbit's urogenital ridge are not so perfect as they are in the chick at the fourth day—the period at which Waldeyer depicts the germinal epithelium [1]—yet it may be assumed that

[1] Waldeyer, *Eierstock und Ei*, p. 120, assigns a much greater distribution to

the thickening of the epithelium seen towards the inner side of the urogenital ridge of this rabbit is the beginning of its germinal epithelium. The section from which the drawing (fig. 27) was made came from about the middle of the ridge, and it was only in this neighbourhood that the thickening was seen.[1] With regard to the characters of the cells of the germinal epithelium, it is to be noted that they stain freely and that those next to the peritoneal sac are columnar, whilst the deeper ones are more or less oval and have a conspicuous nucleus.

The tissue upon which the rabbit's germinal epithelium rests, and which, of course, belongs to the urogenital ridge, consists of a network of branched anastomosing cells, many of which possess a large nucleus and nucleolus. The relation of this tissue to the germinal epithelium is most important. Where the two structures are in contact the basement line of the epithelium is not apparent, more particularly where the epithelium is thickest; and the union is so close that the processes of some of the branched cells are prolonged between the cells of the germinal epithelium.

The conclusions which it seems reasonable to draw from this account of the genital eminence of the rabbit is that that structure from its commencement consists of—A, Stroma; B, Germinal Cells; C, Blood-vessels.

Since it is quite clear from what has gone before that the human embryo has a urogenital ridge and germinal epithelium almost the same as in the chick or rabbit, it seems reasonable to suppose that it might also possess a genital eminence, and that the latter would originate in the same way as in the animals that have just been mentioned. A human embryo two-thirds of an inch long, and whose arms and legs were short and devoid of flexures, seems to place this question beyond the stage of hypothesis. A section through the middle of the urogenital ridge of this specimen shows that there is a distinct elevation towards its front and inner side, and not very far from the base of the mesentery. This elevation mainly consists of mesoblast, and it seems reasonable to assume that it represents an early

the germinal epithelium of the chick than can be seen in rabbits, or, I think, in human embryos.

[1] Compare Waldeyer, *loc. cit.*, pl. v. fig. 50.

stage of the genital eminence. The arrangement of the neigh-
bouring epithelium bears out this assumption. Near the place
where the Wolffian duct lies in the urogenital ridge (fig. 28)
the peritoneal epithelium is nearly flat, but as it nears the
eminence which has just been mentioned its cells become larger
and more columnar, and have many of the characters of germinal
epithelium. In addition, the depth of the epithelium over the
convexity of the eminence is greater than anywhere else. This
thickening is due to an actual increase in the thickness of the
germinal epithelium, and, besides, a number of its cells are
mingled with those of the underlying mesoblast. These deeper
cells are somewhat irregularly disposed, and indistinguishable
from those which cover the surface. Making every allowance
for the nature of the material which has afforded the foregoing
information, I think that it would not be rash to conclude that
the human embryo has a genital eminence almost identical in
character and origin with that of the rabbit. Before taking leave
of the human genital eminence a word may be spoken about
the mesoblast which helps to form it. This tissue consists of
quantities of small mesoblastic cells not much larger than lymph
corpuscles. These elements are of various shapes—round, oblong,
or spindle-shaped, and each possesses a nucleus. Whether any of
them are branched at this early stage is hard to tell, because they
are all so closely crowded together, much denser than in rabbits.

This point having been arrived at, the next question refers
to certain peculiarities which are attributed to the cells of the
germinal epithelium. Perhaps the point at issue may be made
clearer by the following quotation :[1]—

"This 'sexual eminence' is present in the early stages of both
sexes. In both the epithelium consists of several layers of short
cylindrical cells, a few of which are conspicuous on account of their
size and their possessing a highly refractive oval nucleus of consider-
able bulk; in both the underlying thickened mesoblast consists—as in-
deed at this epoch it does generally in all parts of the body—of spindle-
shaped cells. The larger conspicuous cells of the epithelium, which
appear to have quite a common origin with their fellow cells, and to
arise from them by direct differentiation, and which are seen at the
first in male as well as in female embryos, are primordial ova or
primitive germinal cells. Thus in quite early stages it is impossible
to detect the one sex from the other."

[1] Foster and Balfour, 2nd edit., p. 221.

Assuming that, so far as the chick is concerned, these observations are correct, we will now endeavour to see whether they can be applied to either the rabbit's or human embryo.

After the description which has been given of the rabbit's germinal epithelium it is unnecessary to institute tedious comparisons. Although that animal does not possess primitive germinal cells which conform exactly to the description of those of the chick, nevertheless the deeper ovoid cells of its germinal epithelium may be their representatives. It is true that it can hardly be said that "they are conspicuous on account of their size," or that they "possess a highly refractive nucleus of considerable bulk"; but that some of the deeper cells of the rabbit's germinal epithelium betray a distinct resemblance to the primordial ova of the chick, and that they appear to become an integral part of the genital eminence cannot be denied. Moreover, speaking more particularly of ova, when it is considered how, at maturity, the avian ovum differs from that of the mammal, ought we to wonder that their early stages are not quite the same. It seems as though the ovum of the bird began to assume its peculiar characters, especially largeness, from its very beginning; but that in the rabbit and human embryo the germinal cells hardly acquire such a definite individuality.

The quotation raises another question, viz., the characters of the mesoblastic tissue which helps to form the genital eminence. It is said that in chicks at the fourth day of incubation the mesoblast which underlies the germinal epithelium consists of spindle-shaped cells; but Waldeyer,[1] also speaking of chicks at the fourteenth day of incubation, says that the tissue in question consists of ordinary small round or flattened cells joined to one another by branches, and that they are the same as the connective-tissue cells which at this period are found throughout the embryo. In addition, he mentions that a slight augmentation of this tissue causes the elevation which constitutes the genital eminence, and in his figure a colony of nucleated cells is indicated in this position. The whole of this description, the correctness of which I have assured myself, might be applied to the rabbit's embryo, with the exception that in them there is hardly any increase in the density of the

[1] *Loc. cit.*, p. 136.

stroma which underlies the germinal epithelium. It is to be understood that this statement applies to very thin and highly magnified sections. In human embryos which show the earliest stages of the genital eminence, the tissue subjacent to the germinal epithelium is rich in cells of various shapes and sizes, but, owing perhaps to the nature of the material, the network of branched anastomosing cells is not perceptible; however, it is very obvious in the latter stages of the development of the human testicle.

It has been deemed expedient to describe the genital eminence of the rabbit at some length, because, although its histogenesis is most probably the same in the human embryo, yet, as I have often said, the material they afford is seldom good enough to serve as the basis for independent conclusions. Nevertheless, it is easy to understand that, although this be the case, human embryos may furnish a great deal of information which is reliable when supported with evidence derived from examination of other mammals.

When once the genital eminence has become established, its growth proceeds apace. By the seventh week, in human embryos, it is almost equal in bulk to the Wolffian body, and by the tenth week is larger than that structure ; a superiority which it ever afterwards maintains. But before passing to these later stages it is desirable to mention some of the steps by which they are reached. So far the Wolffian body, both in rabbits and in human embryos, has been the main representative of the excretory system. However, the definite establishment of the genital mass determines an important alteration.

Permanent Kidneys.

Before this event the Wolffian body throughout its whole extent seems qualified to perform the duties of a great excretory organ. But a time has arrived when the genital mass originates and grows in its proximity, and henceforth the Wolffian body, instead of fulfilling its manifest destiny—to function as an excretory organ—becomes a mere appendage of the newly arisen sexual gland, and eventually is the epididymis. No immediate alteration in the appearance of the Wolffian body denotes this

change in its destiny, but nevertheless the organism has to make provision for the performance of the functions for which the Wolffian body has presumably become incompetent. Under these circumstances, the permanent kidneys begin to originate. In rabbit's embryo at about the middle of the thirteenth day of intra-uterine life, and in which the genital eminence is comparatively small, and whose Wolffian body is still large, the ureter is the only part of the permanent excretory apparatus which has appeared. This canal springs from quite the hinder end of the Wolffian duct, and running towards the head and behind the posterior part of the Wolffian body, ultimately terminates in the kidney. The latter organ is, as far as I have been able to ascertain from the examination of numerous human embryos and many rabbits, even from its earliest beginning, quite separate and distinct from the Wolffian body (fig. 29). When the kidneys appear the limits of the Wolffian body are very definite, and there is no admixture of its canals with those of the kidney. As for pretending to distinguish the canals of the one organ from those of the other, it would, in my opinion, be exceedingly difficult, or perhaps impossible. If these points are conceded it would seem superfluous to invoke the existence of misplaced Wolffian tubules for the purpose of explaining congenital cystic conditions of the kidneys. Some malformation of the kidney tubules themselves, or of the glomeruli, would afford an equally plausible explanation, and would not necessitate a demonstration of the passage of Wolffian tubules into places where they do not normally exist.[1]

The permanent kidneys seem to me to originate in the rabbit and rat in the manner described by Kölliker.[2] Sections through rabbits at the commencement of the fourteenth day, in my opinion, confirm the statements of that author. After the Wolffian duct has received the whole of the Wolffian tubules it runs a little distance towards the tail end, and terminates in the urogenital sinus. Just before its ending the Wolffian duct receives a canal which closely resembles it in appearance and size. This canal extends forward towards the head, pursuing a course parallel to, but behind, the Wolffian duct, and when it

[1] J. Bland Sutton, " Erasmus Wilson Lectures on Evolution in Pathology," *Lancet*, 1887, vol i. p. 355.

[2] Kölliker, *loc. cit.*, p. 946, figs. 579 and 580.

has arrived behind (*i.e.*, dorsal to) the hinder extremity of the Wolffian body terminates in two or three cæcal prolongations (fig. 29). These latter represent the commencement of the kidney, and they are lined with a single layer of columnar epithelium. This lining differs from that of the ureter, with which it is continuous, merely in the length of its cells: instead of being short columnar like those of the ureter, they are exceedingly long. Although these remarks are founded upon observations made upon rabbits, I have also found that they are applicable to the rat. Before leaving the subject an aggregation of mesoblastic cells (kidney blastema) which surrounds the rudimentary kidney tubules calls for remark. It is present both in rabbits and rats, and gives origin to the parenchyma of the organ. It is not proposed to pursue this question any further at present, but perhaps enough has been said to establish the independence of the permanent kidneys and Wolffian bodies. By the end of the fourteenth day the original prolongations from the ureter have been reinforced by many others, and the permanent kidneys are well established. A transverse section through an embryo rabbit, of the fourteenth day after impregnation, shows the relation of the comparatively well-developed kidney to the hinder part of the Wolffian body and to the genital mass (fig. 30). The genital mass may be seen lying to the front and inner side of the Wolffian body, and immediately behind the latter is the rudimentary kidney. Longitudinal sections show that by this time (fourteenth day) there is in rabbits a close correspondence between the antero-posterior-limits of the genital mass and those of the kidney, the former, of course, lying in front of the Wolffian body, the latter occupying a corresponding position behind it. Moreover, by this time the Wolffian body has become slightly curved, the concavity of bend being towards the middle line, and embracing the genital mass. For this reason it is impossible in a single longitudinal sagittal section to demonstrate all the foregoing points; a series must be examined. If, for a moment, attention be given to the section of the fourteen-day embryo (fig. 30), the elaborate structure of the Wolffian body is evident; tubules and glomeruli may be seen in great profusion. The sexual gland adheres to its inner side by a broad base, and its substance is

continuous with that of the matrix of the Wolffian body. Under low powers the genital mass looks not unlike ordinary lymphoid tissue, but highly magnified it consists of a very delicate stroma of branched anastomosing cells with a great abundance of round, unbranched, nucleated elements entangled in the meshes (fig. 32). A glance at the kidney is sufficient to prove its rudimentary nature, for it consists of a collection of nucleated cells, contained in a meshwork of branched, nucleated, anastomosing cells, penetrated by a few tubules, offshoots from the ureter. The entire independence of the kidney substance from that of the Wolffian body is very obvious.

Human Genital Mass.

In the rabbit at the fourteenth day the Wolffian body still reaches from the diaphragm to the pelvis, and, roughly speaking, the middle third of its posterior surface is in contact with, but distinct from, the developing kidney; further, it is apparent that the side of the Wolffian body away from the kidney is in relation with the genital gland (fig. 31).[1] The next step is to see how far these observations are applicable to the human embryo.

In a human embryo at about the fifth week of intrauterine life the genital mass, or sexual gland, was a prominent object (fig. 32). It lay rather nearer the outer side of the Wolffian body than is the case in the rabbit, and the section which passes through its midst also divides the lower part of the kidney. As far as I can judge, the Wolffian body of this embryo is normal so far as its histology is concerned, but in a little while a most interesting abnormality of its hinder end will be referred to. However, our present object is to ascertain the relation of the genital gland and Wolffian body to the kidney. It may be said at once that these relations are the same as those which have just been noted in the fourteen-days' rabbit, the only difference being that the sexual organs are not quite so much in front of the kidney as they are in that animal, but more to the outer side. The sexual gland also betrays in its structure another divergence. Even when examined under low powers it

[1] This is more apparent in sections nearer the head than that drawn in Plate II., fig. 30.

is clear that many of the cells which compose it are arranged in columns which radiate from the centre towards the periphery. This feature was not visible in the rabbit, but in this and other human embryos it is very obvious, and may indicate, I think, the commencement of the seminal tubules.[1] Some of the sections obtained from this specimen show that a layer of cubical epithelial cells covers the surface of the genital mass, but, with the exception of the point which has just been mentioned, and which relates to the disposition of the cell elements, the histology is not quite so definite as in the rabbit. The material is hardly good enough to justify very positive statements, but it is quite clear the genital mass consists of two sorts of cell elements; the most conspicuous are those which have been said to have a tendency to arrange themselves in columns, and these are fairly large, deeply stained, unbranched, nucleated cells; the others are situated between and amongst the latter; they are nucleated, but do not stain so well, and are irregular in outline, perhaps branched. It is important to notice that, although the Wolffian tubules are very close to the genital mass, yet they do not penetrate into its substance.

Following onwards the natural sequence of events, two changes which take place at the same time would naturally call for notice. One of these changes is histological, and has to do with the development of the seminal tubes and those of the epididymis; the other is anatomical, and produces the mesentery of the Wolffian body and testis, a structure by means of which those organs become more free and mobile in the abdominal cavity.

Before raising these questions it seems appropriate to mention the abnormality which, as was said before, affected the hinder part of theWolffian body and genital mass of the embryo which has just been described.

Fusion of Wolffian Bodies—Synorchis.

This is the earliest abnormality which has been met with in these researches, and the embryo in which it was found was about two-thirds of an inch long, and its arms and legs

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[1] The expression " tubules " is, of course, incorrect, because these structures are solid columns of cells and possess no lumen.

were already beginning to exhibit incipient flexures. In all respects this specimen seemed to be normal and in good condition, but, at its pelvic end, the Wolffian bodies of opposite sides were fused for a few sections. This part of the organ, viewed in section (fig. 38, p. 59), was exactly like a horse-shoe kidney. The upper part of the Wolffian body, as I have said before, seemed quite ordinary, and a normal genital mass grew in relation with it (fig. 31).
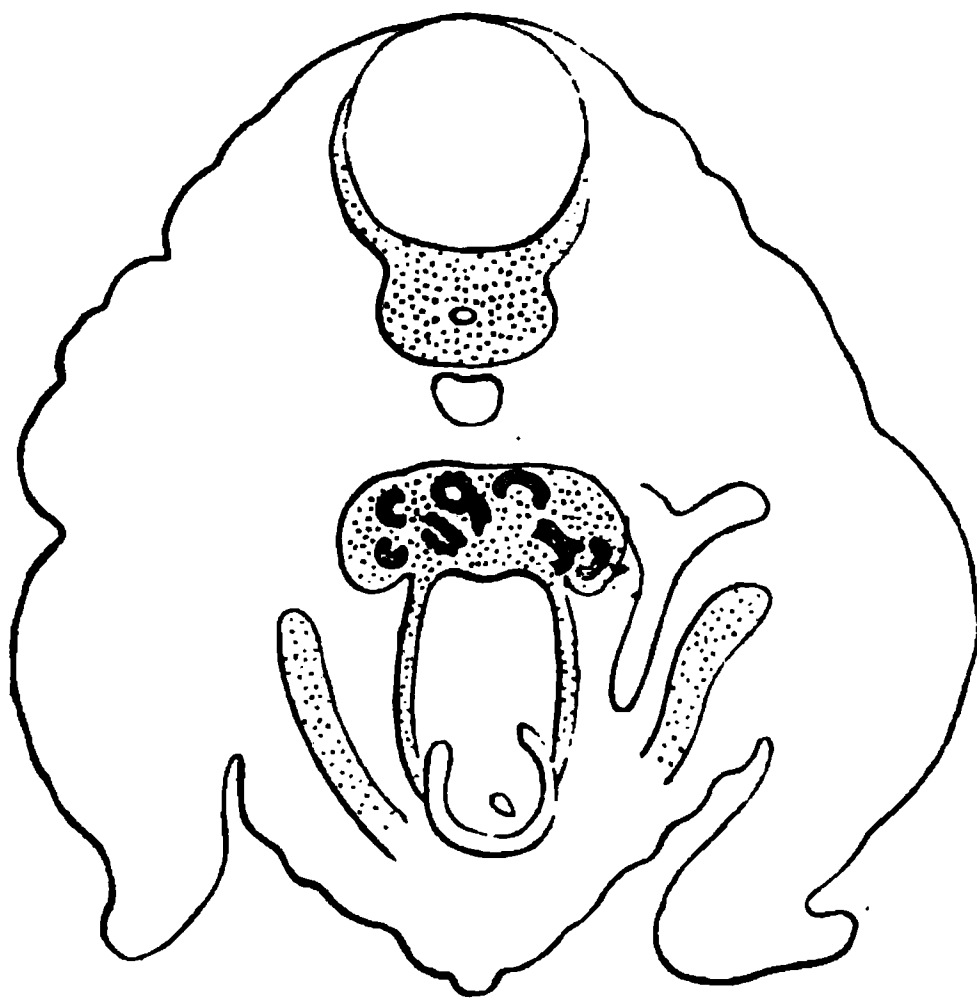
Fig. 38.—Human embryo sixth to seventh week.   The Wolffian bodies are blended towards their hinder ends.

It is interesting to speculate upon the condition which might have been found in this case had the embryo ever grown to maturity. Without doubt the testes must have been united to one another. Such occurrences are not unknown, but must be infinitely rare.

Although systematic writers are accustomed to speak of union of the testis, I am not aware of more than one really authentic instance. This rare case is narrated by Geoffroy Saint Hilaire,[1] who was indebted for the details to Breton and Charvet, both of whom seem to have been very competent observers. Perhaps I may quote Mr Curling's[2] translation of the paragraph, because he

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[1] Geoffroy Saint Hilaire, *Histoire des Anomalies*, 1832, t. i. p. 542.   The doubtful case is by Acrell, in the *Schwed. Abhandl.*, t. xii. p. 19.

[2] Curling, *On Diseases of the Testis*, 4th edit., 1878, p. 6.

has alluded to the circumstance and adds that he believes the case to be unique. "An infant was born at Vizille in 1812: several physicians consulted respecting the child's sex and were of different opinions; they decided, however, to inscribe it in the registers as a girl. It died at the age of eighteen months, and was dissected by Breton, who recognised a complete hypospadias. The scrotum was bifid and empty; and the two suprarenal capsules, as well as the two kidneys and the two testicles, were joined together in the middle line. The spermatic arteries and veins, vesiculæ seminales and vasa deferentia exhibited nothing remarkable, each half of the double testicle receiving its particular vessels." Curling proceeds to mention a case of synorchis which Sedillot found whilst examining a recruit, but there is no evidence beyond the mere surmise. Saint Hilaire also alludes in doubtful terms to another case. It is evident that the account which has just been quoted is wanting in many important particulars. For instance, it is not said whether the bodies of the testes were fused or their epididymes, or what relation the abnormal gland had to the other abdominal contents. Under ordinary conditions the mesentery separates the testes, but in such circumstances as are being discussed, it must have become modified. In the case depicted (fig. 38, p. 59) it is clear that the Wolffian bodies fuse just behind the posterior end of the alimentary canal. Curiously enough, in this embryo the kidneys themselves blended for a little way at their hinder extremities, but none of the other paired organs were united.

Mesorchium and Mesovarium.

As far as we have at present traced the development of the genital system, either in rabbits or in human embryos, the determination of the sex, in spite of that which Egli[1] and Waldeyer have said, seems with our present knowledge an impossibility. Whether the radiating arrangement of the unbranched cells of the genital mass, which is seen in some human embryos, may be an indication of the male sex, is of course a matter of doubt, and incapable of direct proof. However, the events which now occur speedily set all doubts at rest. Whether the embryo is destined

[1] Egli, Th., *Beiträge zur Anat. und Entwicklungsgeschichte der Geschlechtsorgane*, Zürich, 1876.

to belong to the male or female sex has no influence upon the
alterations which take place in the relations of the Wolffian
body to the dorsal wall of the abdomen, or in the alterations
which take place in the relations of the genital mass to the
Wolffian body. Important modifications take place in these
particulars, either in males or females, and since they are far
advanced long before the histological details of the sexual organs
are perfected, I will consider them first.

Fig. 39.—Human embryo (seventh week); section towards middle line. *A.W.*,
portion of Wolffian body which atrophies; *G.M.*, genital mass; *W.T.*,
Wolffian tubules; *W.D.*, Wolffian duct; *M.D.*, Müllerian duct.

The process by which the genital mass is constricted from the
Wolffian body, and by which the latter is freed from the dorsal
wall of the abdomen, takes place almost directly after the geni-
tal mass has appeared.   A glance at fig. 37, p. 48, which was made
from a transverse section through the genital eminence of a
rabbit during the thirteenth day of intrauterine life, shows a faint

constriction at the junction of the genital mass with the Wolffian body; and, moreover, the latter, in proportion to its size, possesses a narrower dorsal attachment. Although these particulars are not so obvious in fig. 31, which was made from a transverse section through a human embryo of about the fifth week, yet indications of their presence are not wanting. However, on the fourteenth day the Wolffian body of the rabbit possesses a broad but distinct mesentery of its own (fig. 30), and the same statement holds good for human embryos which have reached somewhere near the sixth week of intrauterine life. In transverse sections made through human embryos at that period the Wolffian body has a well-marked mesentery, which is attached to the dorsal wall of the abdomen just external to the kidney, and in addition there is an obvious constriction between the Wolffian body and genital mass. Both in human embryos and in rabbits the processes which have commenced in this manner continue to progress, until at last the Wolffian body has a distinct mesentery, which becomes the mesorchium or mesovarium, and the genital mass is merely fastened to the Wolffian body by a narrow neck (fig. 39, p. 61).

The changes by which a mesentery is formed for the Wolffian body and genital mass occur in exactly the same way in either the male or female sex, but whilst they are taking place the histology of the genital mass has undergone great alterations, and moreover the Wolffian body has been profoundly modified.

Development of Tubuli Seminiferi.

Perhaps it will make that which follows clearer if I begin by pointing out the order in which the process of development will be followed. It is quite unnecessary to premise that the genital mass, although at first seemingly indifferent and suitable for conversion into either ovary or testicle, becomes transformed either into a highly complicated tubular organ or into a cell-laden mass. It is not proposed in this place to discuss the conversion of the genital mass into an ovary, but to endeavour to show how it gives origin to the connective tissue and tubules of the testicle, and how the latter acquire their needful efferent channels. Although human

embryos are obtainable suitable for showing the larger details, nevertheless they are rarely good enough to demonstrate the more minute histological changes. It is not necessary on this account to repudiate them altogether, but it makes it desirable to check all conclusions drawn from them by the examination of more reliable material. Under these circumstances the histology of the developing testicle of the rabbit will, first of all, be mentioned, and afterwards the development of the human testicle will be illustrated. But, as we proceed, it will be found that rabbits need only be used in the earliest stages, and that for the final ones human embryos of a satisfactory character are at hand.

We have already described the formation of the genital eminence of the rabbit in its earliest stages. It is unnecessary to recapitulate either its mode of origin or its relation to the Wolffian body. It will suffice to recommence the consideration of its histological structure by referring to the appearance which it presents during the first half of the thirteenth day. Since these have been described in detail, they only call for brief allusion. It may be remembered that from its earliest commencement the genital eminence consisted of a network of branched anastomosing cells, which was continuous with the stroma of the Wolffian body. The meshes of this network contained numerous nucleated unbranched cells, which were in continuity with, and the same as, the germinal epithelium (fig. 26).

The part of this account around which a great deal of controversy turns is the exact relation of the cells of the germinal epithelium to the rest of the genital eminence. Kölliker[1] states his belief that the germinal epithelium only gives origin to the ova and to Müller's duct; but, at the same time, he says that many authors think that it has a much greater rôle to play. The preparations from which the preceding account was written were exceedingly successful, and, in my opinion, showed that the germinal cells penetrated almost half-way towards the base of the genital mass. The embryos had been stained in picro-carmine, by which the germinal cells were deeply coloured— much more deeply than those of the stroma. Janošik gives a description very similar to that which I have endeavoured to

set forth; but that author does not, in my opinion, lay sufficient stress upon the stroma of the genital mass. He has compiled an excellent epitome of the opinions held by many recent authors.

Although at the beginning of the thirteenth day the germinal epithelium of the rabbit has those appearances, nevertheless at the fourteenth day it still looks almost uniform in structure. Transverse sections made through the genital eminence during the latter period show that its surface is covered with a layer of small cubical cells, and that its bulk consists of a network of branched anastomosing cells, with a number of unbranched nucleated cells in the meshes (fig. 32). There is no feature about the histological appearance of these unbranched elements to positively identify them with the germinal cells; we can only assume, from the preceding observations, that they have been derived from that source. Whilst in this indifferent stage the genital mass, when looked at with a low power, is very like lymphoid tissue. Even high powers do not dissipate this impression, more particularly as regards the stroma; but the cells in the meshes do not at all resemble lymph cells; they are larger, and have a more clearly defined nucleus, and a larger quantity of protoplasm.

Although human embryos are seldom good enough to demonstrate such minute histology as that which has been described, nevertheless the genital mass of a human embryo (fig. 39, p. 61), of about the seventh week, was almost the same as that of the rabbit at the beginning of the fourteenth or end of the thirteenth day. Both as regards stroma and unbranched cells the similarity is quite clear.

Remembering that the genital mass consists of a network of branched anastomosing cells, in the meshes of which are numbers of round nucleated elements, we may now proceed to observe how the seminal tubules originate in this tissue. The commencement of the process may be seen in the rabbit's embryo during the fourteenth day. About this time an alteration may be noticed in the tissue which underlies the surface layer of cubical epithelium. This change consists in a more or less complete disappearance of unbranched cells from the stroma in this situation, and in the stroma itself forming a narrow peri-

pheral zone, which differs from the central part in the smaller and more elongated character of its meshes (fig. 32). This layer, which represents the commencement of the tunica albuginea testis, is arranged with the long axis of its meshes parallel to the surface epithelium. Towards the centre of the sexual gland other alterations may be seen in the stroma, for its meshes
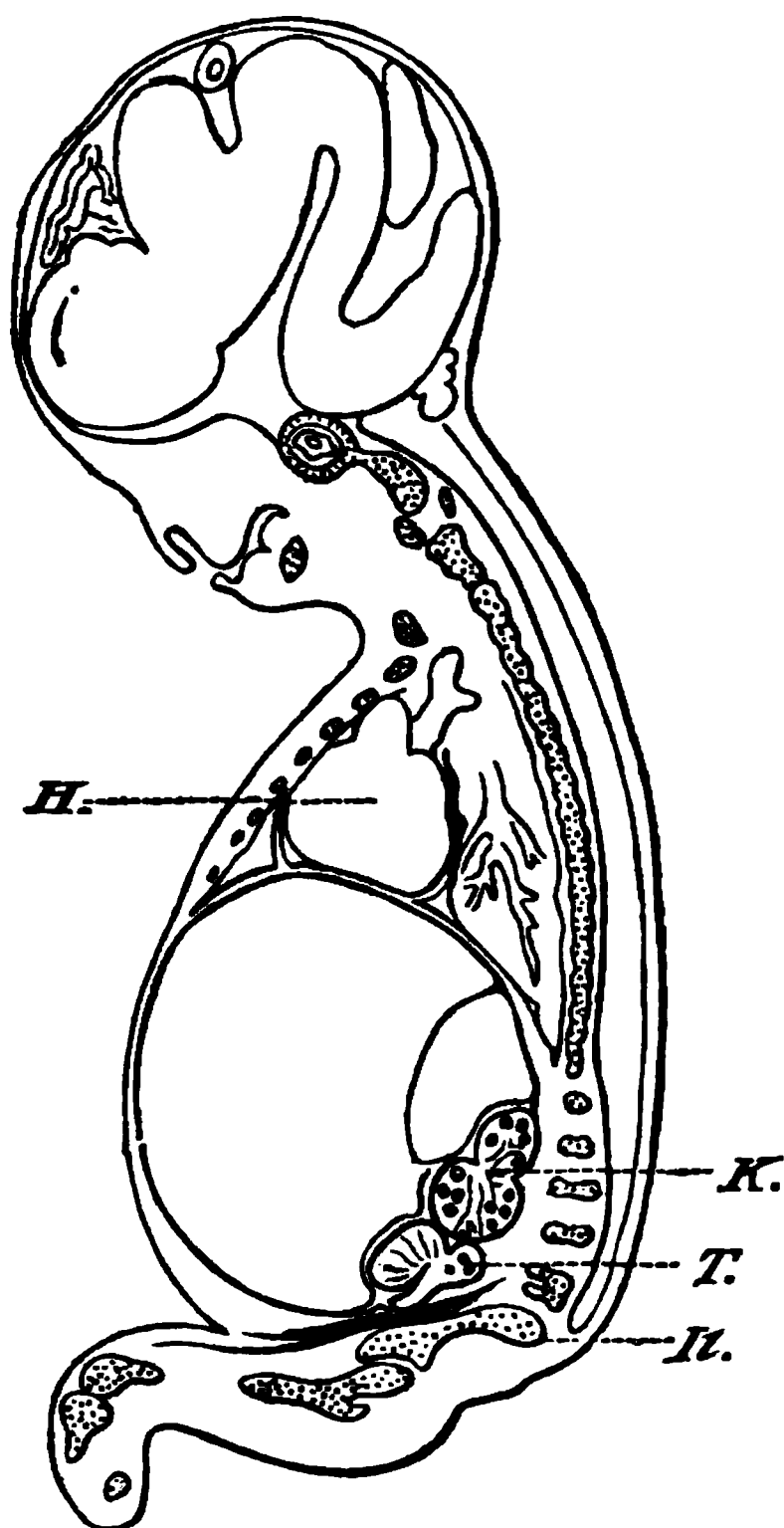
Fig. 40.—Relation of testis *T.* and Wolffian body to kidney *K.*, ilium *Il.*, and to the front wall of abdomen ; *H.*, heart.

have in places become exceedingly large, so that aggregations of the unbranched cells are observable. That this betokens the beginning of the seminal tubules will, I think, be conceded after the testicle of a human embryo of about the tenth week has been described. Before entering upon these particulars it may be as well, for reasons which have frequently been stated, to give a brief account of that specimen (fig. 40). The length of a

longitudinal section through the body and trunk was one inch and three-sixteenths, the limbs were well formed, and possessed, besides proper joints, well-marked fingers and toes. The testes and Wolffian bodies lay in contact with, but posterior to (*i.e.*, below, in the erect posture), the kidneys; and as this is a point which will be discussed further on, we may now proceed to examine the histological structure of the testes.

At this stage of development the sexual gland has the general contour of the perfect organ and the Wolffian body has begun to have a likeness to the epididymis. The surface of the testicle is covered with a layer of cubical epithelium, and its interior is made of a stroma of large branched anastomosing cells and of numerous unbranched nucleated elements. The epithelial covering has no peculiarity, and may therefore be passed over;

St.

Fig. 41.—Section through Testis at tenth week to show developing seminal tubules and stroma. *Ep.*, epithelium; *T.A.*, tunica albuginea; *St.*, stroma; *T.T.*, tubuli testis. × 250.

but the arrangement of the other constituents, more particularly of the unbranched cells, is very interesting. If the microscopical examination is begun with a low power, such as a third of an inch, it is easy to see a rudimentary tunica albuginea beneath the surface, and this is developed, as in the rabbit, by the meshes of the stroma becoming parallel to the surface epithelium, and by the disappearance of unbranched cells from its meshes. Throughout the rest of the gland the stroma, under low powers, has no peculiar feature. If now we pass on to the unbranched

cells, or, as in future they may be called, spermatic cells, it will be found that, instead of being uniformly scattered throughout the testicular stroma, they have disposed themselves along certain paths. The irregular columns which have thus originated have an arborescent appearance, which indicates that they are the commencement of the seminal tubes (fig. 41, p. 66). As these rudimentary tubules approach the tunica albuginea they loop backwards again towards the centre of the testicle. Moreover, near the junction of the testicle with the Wolffian body, or, as in future it may be called, the *isthmus testis*, the converging tubules are joined to one another by numbers of spermatic cells, which are irregularly arranged along the long axis of the testicle, and represent the rete testis (see also fig. 33).

Placing aside, for the moment, the development of the efferent channels of these newly developed tubules, we may proceed to consider the more minute histological characters. For this purpose an amplification of about 250 diameters is enough, and what follows relates to the testicle of a human embryo at about the tenth week of intrauterine life seen with such a power (fig. 41, p. 66). So far as its general arrangement is concerned the stroma is the same as that which has been described already in the developing testicle of the rabbit. But it is to be noted that the strands which form the meshes of the stroma are a great deal thicker.

Moreover, the thickness of the strands of the stroma is not the same everywhere; they are thinnest towards the periphery, but become thicker towards the isthmus testis. Near the tunica albuginea it is easy to see that any particular portion of the testicular stroma is made of branched anastomosing cells, which possess large, granular, oval nuclei and nucleoli; but as the strands of the stroma approach the isthmus it is clear that, although its individual cell elements are the same, yet their relations to one another have altered. The alteration is in the shape of the cells, which, instead of being provided with long and tenuous branches, have either none at all, or, in their place, thick and short protrusions of their substance, and these are continuous with other cells. Owing to these modifications there are places near the isthmus testis and near the rete where the stroma is made of strands of cells which seem to possess no

branches, and which, lying side by side, closely resemble endothelial plates. Where this is the case it would be easy to mistake the unbranched stroma cells for endothelial plates, but, even where the likeness is strongest, traces of a meshwork are here and there discoverable. These appearances have been particularly mentioned because of their importance when taken in relation with certain columns of cells which have been observed in hilum of the mature testicle. Dr Klein [1] describes and figures certain "interstitial epithelial cells" in the hilum of the mature testicle of the cat, and attributes them to the tubules of the Wolffian body, of some of which he considers them to be the remains. Judging from Dr Klein's very beautiful figure, and from specimens of cats' testicles, the structures in question look to me much more like the cells of the developing stroma, such as I have just described. This is not intended to imply that no tubules from the Wolffian body enter the hilum of the testicle (or ovary), and in that which follows evidence will be forthcoming upon this point.

Before taking leave of the stroma of this testicle, it is hardly necessary to do more than mention that it is continuous at the isthmus testis with the stroma of the Wolffian body. The latter has already been depicted and described (fig. 25), and calls for no further mention. It only differs from the stroma of the body of the testicle in not forming strands, and in an absence of collections of endothelial-looking stroma cells, such as have just been alluded to.

The next question that demands attention is the histology of the developing seminal tubules, and of the spermatic cells which compose them. If a clear idea has been conveyed of the rudimentary testicular stroma this should prove an easy task. The spermatic cells stain more deeply than those of the stroma, and each one has a central nucleus and nucleolus. Their shape is round or oval, and they have no branches whatever. It has been said that the spermatic cells are arranged in irregular arborescent columns, and now, under high powers, it is seen that these columns lie in irregular spaces in the stroma (fig. 41, p. 66). These latter are not anything special, and merely look like enlargements of the meshes of the stroma; but the outline of their

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[1] Klein, *Atlas of Histology*, p. 269 and 286, pl. xxxix. fig. 8.

walls is more regular and definite, and the cells which form their boundaries are usually flat or spindle shaped (fig. 41, p. 66).

The columns of spermatic cells which lie in these spaces have no particular arrangement, but their tendency seems to be to occupy the centre, and not to lie in contact with its walls. However, it is most interesting to observe that, whilst in this rudimentary state, the spermatic tubules are solid, and composed of small round or oval cells arranged without any particular order.

Owing to the kindness of Mr Hy. Butlin and Mr A. Bowlby I have had the opportunity of examining histological sections of sixteen malignant tumours of the testicle. It was impossible to ignore the great likeness of their tissues to those of developing testis. A stroma of branched anastomosing cells was visible in portions of many of them, and their unbranched elements were practically indistinguishable from the unbranched spermatic elements which have just been described. In none of these malignant tumours could I discover, even after several careful examinations, any elements to which I myself should apply the term " epithelium." On the contrary, specimens which would accord with the definition of a cancer seem to do so because their unbranched elements were collected into irregular columns, like developing seminal tubules.[1]   With regard to the existence of epithelium in tumours of the testicle the foregoing statement requires to be qualified to this extent, namely, that I have more than once seen in them tubules or loculi lined with a single layer of columnar epithelium. However, in those cases there was no real resemblance to any ordinary form of carcinoma, and the tumours usually contained cartilage and other mesoblastic elements.

If the order of development was strictly followed the Wolffian body would again claim attention. That organ has, whilst the body of the testicle has been developing, undergone great changes, and is in course of being converted into the epididymis. But to avoid leaping from one branch of the subject to another it is more convenient to carry the development of the body of

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[1] E. Rindfleish, *Lehrbuch der Patholog. Gewebelehre*, Leipzig, 1886, p. 579, quotes from Birch-Hirschfeld, " that the cells, as in cancers of kidney, liver, breast, and testicles, come from the epithelium of the gland canals."

the testicle a stage further, and then return to the Wolffian body.

We have just seen that the seminal tubules of the human embryo, and also the rete testis, are laid down as early as the ninth or tenth week of intrauterine life, so that it only remains to trace their future modifications.

The appearance of the human testicle at the third month has been figured in the accompanying sketch (fig. 33). The seminal tubules are more numerous and thicker, and the rete testis is very much better marked than in the younger embryo. This is due to an increase in the numbers and in the size of the spermatic cells. Both the seminal tubules and the rete testis are solid columns of unbranched, deeply staining, nucleated cells. Evidently the term " tubule " ought not to be applied to these structures until they have acquired a lumen. At the sixth month of intrauterine life the arrangement of the spermatic cells has not altered, but the seminal tubules are larger, and have begun to be exceedingly tortuous. I have no exact information as to when the centre of the seminal columns begins to clear, but in the testicle of a young goat, six months old, there was a very slight indication of a clearing towards the axis of the column.

The phases through which the connective-tissue stroma of the developing testicle passes are comparatively simple. Although up to the tenth week the stroma of the human testicle consists of branched elements, yet by the twelfth week the cells are in places elongated and beginning to be spindle shaped (fig. 33); by the fifth month they have advanced a long way towards being fibrous tissue, and, of course, this is its ultimate destiny (fig. 35). As for the interstitial cells, which may be seen in the stroma of well-prepared sections of adult testicle, it has been said that they are formed from remains of the Wolffian body. The time has now arrived at which we may conveniently endeavour to ascertain the relation of the tubules of the Wolffian body to those of the testicle; and as this important branch of the subject is followed, light will be thrown upon this important and interesting question.

As suitable material is at hand, I propose to confine the rest of this description to human embryos. But, before entering upon

particulars, it is desirable to endeavour to convey an idea of the general appearance and relations of the genital mass at the time when the changes which are about to be mentioned begin. In a human embryo five-eighths of an inch long, and at about the seventh week of intrauterine life, the Wolffian body and genital mass lay near the lower end of the kidney, and just overlapped that organ. The genital mass was in the indifferent stage, and it is impossible to be sure of its ultimate fate; it is attached to the middle third Wolffian body by a narrow isthmus (fig. 39, p. 61). The Wolffian bodies themselves are not by any means so parallel to one another as when first developed, and lie obliquely, with their lower ends converging. There is no difficulty in observing that its structure has undergone great alterations. If we begin with a section near the middle line, and therefore dividing its lower part, it is evident that the foremost glomeruli, although larger, are faintly stained, and their tissues granular,—appearances which indicate that they have begun to degenerate and atrophy. The tubules, on the other hand (fig. 39, p. 61), are exceedingly perfect; their lumens are capacious, and their lining membrane of short columnar epithelium is very distinct (see also figs. 24 and 25). Turning now to a section which divides the upper and outer part of the Wolffian body, quite a different sort of tubule comes into view (fig. 34). These may be said to begin in a collecting tube, which is a continuation forwards of the Wolffian duct. I have purposely refrained from calling this the Wolffian duct, to mark that its characters are decidedly dissimilar, being smaller, and having hardly any lumen. The tubules, which extend from the collecting tube into the hilum of the genital mass, are still more remarkable. In this and other specimens about twenty tubules leave the collecting tube at right angles, and extend into the hilum of the genital mass. At their beginnings these canals have hardly any lumen, but they expand as they run onwards, and gradually acquire one. Their epithelium is peculiar in that it stains exceedingly dark, and in being smaller and more cubical than that of ordinary Wolffian tubules[1] (fig. 34). When we consider the course and the relation of these peculiar

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tubules to the genital mass, it does not seem unreasonable to suspect that they are the commencement of the tubuli efferentia. Waldeyer has given semi-diagrammatic representations of these tubules;[1] the human embryo which he used was 9 cm. long, and therefore much older than that which I have been describing. Waldeyer divides the Wolffian body into two parts: a sexual, consisting of these tubuli efferentia; and a urinary, consisting of the more capacious tubules and glomeruli. At present we are not concerned with the female type, but it may not be out of place to note in it the destination of the genital mass, and of the sexual and urinary parts of the Wolffian body; the genital mass becomes converted into the ovary; the sexual part of the Wolffian body remains as the structure which Waldeyer calls the "Epoophoron"; and the urinary part also persists, and is called by the same author the "Paroophoron." The terminology of these remains is exceedingly confused. Authors have not always drawn a clear distinction between the sexual and urinary portions of the Wolffian body. The former, as we have seen, are smaller, straighter, and less canalised than the others, and have apparently no glomeruli; moreover, they penetrate into the genital mass. The urinary tubules are larger, have a wider lumen, and end in glomeruli, and do not penetrate the genital mass (fig. 39, p. 61). In order to avoid ambiguity, a provisional list of the various names which are commonly applied to these various structures is appended, and has been compiled from the books of Henle, Kölliker, Quain, Waldeyer, &c.

PROVISIONAL LIST OF NAMES.

	In Female.	In Male.
Genital mass becomes	Ovary.	Testicle.
Wolffian body becomes		
A. Sexual part =	{ Epoophoron of Waldeyer. Parovarium of Kobelt. Organ of Rosenmüller. } =	{ Epididymis and its Vasa efferentia or Coni vasculosi.
B. Urinary part =	Paroophoron of Waldeyer. =	{ A. Paradidymis of Waldeyer, or Organ of Giraldès. B. Vasa aberrantia.

Before I endeavour to trace the process by which, in the

[1] *Eierstock und Ei*, p. 142, also plate vi. figs. 60 and 61.

male, the sexual tubules of the Wolffian body become vasa efferentia, a peculiarity which they betray during the indifferent stage may be noticed (fig. 34). Where these tubules open into the collecting tube they are small, and have hardly any lumen, but as they run towards the hilum of the ovary they expand, and have at last a considerable dilatation (fig. 40).

· The meaning of this seems obscure, and, as far as I am aware, has not been noticed before. However, Waldeyer made his semi-diagrammatic figures from older human embryos, and I have reason to think that in them the dilatation is not discernable.

The sex of the embryo from which the foregoing observations were made could not be distinguished. Its genital mass was in the indifferent stage, and had neither tunica albuginea nor the rudiments of seminal tubules, and therefore it affords no clear evidence of the way in which a communication is effected between the tubules of the Wolffian body and those of the testicle. The human embryo of about the tenth week may carry us a step further (fig. 40, p. 65). This embryo has already been mentioned, and the development of the body of its testicle has been traced up to the point at which it consisted of solid arborescent columns of cells converging to a rete testis all imbedded in a stroma of branched anastomosing cells, and surrounded, except at the isthmus, by a tunica albuginea. The Wolffian body of the embryo, like the last, consisted of two portions distinguished by the dissimilarity of their tubules; these parts being, of course, those which have been called the sexual and the urinary. The urinary part of the Wolffian body, if we may judge from the perfection of its structure (fig. 25), is at the height of its development, and in size far exceeds the sexual part. This latter contains the curious tubules which have just been described and identified with the vasa efferentia. They are a quarter the size of the urinary tubules, and their epithelium stains darkly; they run nearly at right angles from the collecting tube, and extend into the hilum of the testicle, where they are slightly dilated, and have a lumen. With regard to this last point it is interesting to note that it is exceedingly hard to say whether either the foremost part of the collecting tube, or the portions of the tubules (tubuli efferentia) nearest to them have a real lumen. However, in the hilum of the

testicle the latter are canalised, and some of them contain a structureless substance, which stains faintly, and is doubtless some form of secretion. This embryo is, without question, of the male sex, and it shows, at least, that the sexual tubules reach the body of the testicle.

But, before it is possible to form any conception of the way in which the sexual tubules of the Wolffian body become continuous with the rete testis, perhaps it may be desirable to call to mind the anatomical arrangements at this particular moment. Both in the ten weeks' embryo, and in one of twelve weeks (fig. 23), there is, at the isthmus of the testicle, no line of demarcation whatever between the parenchyma of the testicle and that of the Wolffian body. The aggregation of spermatic cells which constitutes the rete testis is in the stroma, and has no distinct limits (fig. 23). Moreover, the tubules of the sexual part of the Wolffian body or vasa efferentia extend into the hilum of the testis, and gradually lose their identity, owing to their cells having become disseminated in the meshes of the stroma. But those meshes are full of rounded unbranched seminal cells, so that there is a continuity of cell elements between the rete testis and vasa efferentia. As cell arrangement proceeds in the body of the testicle, these intermediate cells form the last link in the chain which unites the sexual tubules of the Wolffian body to the rete testis. The actual arrangement of these indifferently disposed intermediate elements does not begin in the human embryo until about the sixth month of intrauterine life. The accompanying drawing has been made from the testicle of a human embryo at about the eighth month of intrauterine life (fig. 35), and although it does not demonstrate an absolute physical continuity of cell elements between tubules of epididymis and those of the testicular lobules, yet, in my opinion, such an union does exist. The elements are arranged in irregular and crooked strings, so that no single section could give adequate evidence upon this point.

This account of the process by which an egress is provided for the seminiferous tubes is, allowing for differences in the mode of expression, very like that which Janosik describes for the rabbit and cat. However, the examination of testicles of various animals—dog, cat, goat, and rabbit—inclines me to

believe that the process is not the same in every type, but that the tubules of the Wolffian body may participate in different animals to a varying extent in forming the rete testis. If this surmise be correct, it would tend to explain the various and contradictory accounts which may be read in the voluminous literature of the subject. Under these circumstances, it has been deemed advisable to adhere to one type, and human embryos seem as suitable as any others, and have, therefore, been used. It is not proposed to follow the histological differentiation of the tubules of the testicle and epididymis beyond the process of establishment. But before leaving the subject, a word may be spoken upon the fate of the glomeruli of the urinary portion of the Wolffian body. These have been seen at the height of their perfection in male human embryos of the tenth week (fig. 25). At the twelfth week it was still quite easy to ascertain their persistence; but in the male none could be found at the sixth month, nor at the eighth month.

But, in a specimen of the ovary and broad ligament of a child eight months old, lent to me by Dr Walter Griffith, there were structures near the hilum of the ovary which had the usual characters of glomeruli, except that Wolffian tubules were not traced to them.

It may be gathered from the foregoing that I have not been able, either in rabbits' or human embryos, to confirm Balfour's assertion that the glomeruli receive the testicular tubules.

We are now in a position to mark what becomes, in the male, of the sexual and urinary portions of the Wolffian body. The sexual tubules become the vasa efferentia, whilst the urinary tubules may persist, and constitute the well-known organ of Giraldès. Some of them may even grow, and persist as the vasa aberrantia. These tubules, when present, vary in number, and one of our pupils, Mr Stanley, has dissected a testicle for-me, in which four can easily be made out. This is such an unusual circumstance that I have made a sketch of the specimen (fig. 36).

EXPLANATION OF PLATE II.

Fig. 23. Glomerulus of human Wolffian body. *Gl*, glomerulus; *T*, Wolffian tubule; *V*, afferent and efferent vessels. 7 Hartnack. 4 Eye p.

Fig. 24. Glomerulus of human Wolffian body, seventh week, showing the commencement of the development of capillaries in the glomerulus, the formation of the parenchyma and the tubules. *P*, parenchyma; *T*, tubule; *Gl*, glomerulus; *C*, capillaries; *E*, epithelium of a commencing tubule. 7 Hartnack. 4 Eye p.

Fig. 25. Glomerulus of human Wolffian body at tenth week, showing vascularity of glomerulus and stroma of Wolffian body. *Pr*, parenchyma; *Gl*, glomerulus; *WT*, Wolffian tubule. 7 Hartnack. 4 Eye p.

Fig. 26. Sexual eminence of rabbit, $\frac{1}{13}$ in oil immersion, to show relation of surface epithelium to meshes of stroma. This drawing was from a section close to that shown in fig. 37, p. 48.

Fig. 27. Urogenital ridge of rabbit, beginning of thirteenth day. *M*, mesentery; *GE*, germinal epithelium; *WT*, Wolffian tubule; *WD*, Wolffian duct; *AO*, aorta. 7 Hartnack. 4 Eye p.

Fig. 28. Human embryo, sexual eminence. *GE*, germinal epithelium; *CV*, cardinal vein; *WD*, Wolffian duct; *Gl*, glomerulus. The bulk of the urogenital ridge and its genital eminence consists of mesoblastic cells of various shapes—round, branched, and elongated; these have not been delineated. 7 Hartnack. 4 Eye p.

Fig. 29. Kidney and hinder part of the Wolffian body of a rabbit of thirteenth day. *KB*, kidney blastema; *U*, ureter; *LCT*, loose tissue, which surrounds kidney blastema; *WD*, Wolffian duct; *WT*, Wolffian tubules; *PC*, peritoneal cavity. × 70.

Fig. 30. Rabbit, fourteenth day, to show relation of hinder part of the Wolffian body and genital mass to one another, and to the kidney which has just appeared. *GM*, genital mass; *AO*, aorta; *K*, kidney; *HL*, hind limb; *M*, mesentery. × 25.

Fig. 31. Human embryo, thirty-five days. *GM*, genital mass; *K*, kidney, lower end; *AO*, aorta; *CV*, cardinal vein; *WT*, Wolffian tubules; *Gl*, glomerulus. × 45.

Fig. 32. Genital mass of rabbit, commencement of fourteenth day, to show stroma of branched anastomosing cells, and large, pale, granular cells in its meshes. 7 Hartnack. 4 Eye p.

Fig. 33. Testicle and epididymis of human embryo, at about the twelfth week of intrauterine life. The section is not quite longitudinal. × 25. *ST*, seminal tubules; *RT*, rete testes; *Mesor.*, mesorchium; *Vas. Def.*, vasa deferens; *VE*, vasa efferentia; *IT*, indifferent tissue; *TA*, tunica albuginea.

Fig. 34. Outermost and front part of the same human Wolffian body as that which has been drawn in fig. 3*9*, p. 61. *WD*, Wolffian duct; *CT*, collecting tube; *TE*, tubuli efferentia; *GM*, genital mass. × 45.

Fig. 35. Human fœtus, eight months, to show the cell strings of the mediastinum testes which unite tubules of epididymis to seminiferous tubules. *TE*, tubules of epididymis; *MT*, mediastinum testes; *ST*, seminal tubules; *V*, blood-vessels. × 45.

Fig. 36. Human testicle showing four vasa aberrantia. *T*, testicle; *Hy*, hydatid of Morgagni; *VD*, vas deferens; *Ep*, epididymis; 1, 2, 3, and 4, vasa aberrantia.

ON THE SHORT MUSCLES OF THE POLLEX AND HALLUX OF THE ANTHROPOID APES, WITH SPECIAL REFERENCE TO THE OPPONENS HALLUCIS. By H. St John Brooks, M.D., *Demonstrator of Anatomy in the University of Dublin.* (Plate III.)

THE position held by the anthropoid apes in the animal kingdom, standing next to man, has always made them objects of peculiar interest to the anatomist, and to no part of their organisation (except perhaps the brain) does he turn with more interest than to the hands and feet. In the hand, he is anxious to see whether the deeper structures are as human as the external appearance would lead him to expect, where even the folds and wrinkles of the skin of the palm remind him of his own. In the foot, he is eager to look beneath the surface to ascertain whether it is a hind-hand, or whether, as Professor Huxley believes, the hand-like character is only superficial, and the member is, in all its essential features, a true foot. As I have had (through the kindness of Professor D. J. Cunningham) the opportunity of dissecting specimens of three out of the four genera of anthropoid apes, I have decided to publish a few observations on their anatomy. The number of distinguished anatomists who have written on the structure of these animals might make this appear a work of supererogation, were it not that very material differences occur in their writings, more especially in regard to the small groups of muscles which I propose to describe, viz., the short muscles of the pollex and hallux. The opponens hallucis especially seems to call for attention; Professor Hartmann,[1] of Berlin, states that it is present in all the Anthropoids; it has been described by Macalister[2] in the Gorilla; von Bischoff found it only as a peculiar speciality in the Orang and Macaque Monkey.[3] It is usually regarded as a very rare muscle. In the

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[1] *Anthropoid Apes*, London, 1885, pp. 172, 173.

[2] " On the Muscular Anatomy of the Gorilla," *Proc. Roy. Irish Acad.*, June 1873, p. 506.

[3] *Beiträge zur Anatomie des Hylobates leuciscus*, München, 1870, p. 89.

report of a lecture delivered by Professor Huxley before the. . Royal College of Surgeons of England, in 1864, the following passage occurs:—

"There was present in the specimen (Orang) dissected by Professor Huxley an opponens hallucis, inserted into the middle third of the metatarsal of the hallux ; this has not been described by other authors, nor indeed is there trustworthy evidence of the existence of such a muscle in any of the Mammalia."[1]

It will be well at this point to inquire what is meant by the term "opponens." I adopt unhesitatingly the definition given by Professor Cunningham,[2] and regard the term as properly applied to "any intrinsic muscle of the hand or foot which is inserted into the shaft of a metacarpal or metatarsal bone." Two very distinct muscles, as I shall afterwards show, have been described as the opponens hallucis—one of them a derivative from the tibial head of the flexor brevis hallucis, and therefore homologous to the opponens pollicis of the human hand, and the other derived from the adductor.[3] I may also state that I shall treat these muscles, as they are regarded by Professor Cunningham,[4] not as special groups appertaining to the pollex and hallux, but as portions of the three layers of the manus and pes, which belong to the first digits, and have become enlarged and modified in consequence of their marginal position.

In comparing any group of muscles with the corresponding elements in man, we have not only to note differences, but to inquire what these differences mean. In the case of apes especially, they may differ from man in two ways—(1) their muscles may be arranged on a more archaic or generalised plan, or (2) they may be specialised along other lines than the human, as when the foot takes on hand-like characters; the latter is evidently a more essential difference than the former.

In human anatomy we have four short or intrinsic muscles of

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[1] *Medical Times and Gazette*, 1864, vol. i. p. 596.

[2] *Zoology of the Challenger*, part xvi. p. 187.

[3] Duvernoy has described as an opponens *pollicis* an undoubted part of the abductor in the Gorilla, arising from the anterior annular ligament and inserted into the radial border of the base of the first phalanx of the pollex.—"Des charactères anat. des grands singes pseudo-anthropomorphes," *Archives du Muséum*, t. viii., 1853, p. 107.

[4] *Op. cit.*, p. 19.

the thumb commonly described—(1) *abductor pollicis*, (2) *opponens pollicis*, (3) *flexor brevis pollicis*, (4) *adductor pollicis*. The so-called "flexor brevis pollicis" consists of four distinct parts—(*a*) a strong bundle of fibres arising from the anterior annular ligament and os trapezium, and inserted into the radial sesamoid bone (this is the true radial or outer head, f^1r); (*b*) a fasciculus of fibres which passes from the so-called "inner head" to the outer sesamoid bone (a^1a),[1] this is an aberrant part of the adductor; it is absent from all the anthropoids (with the exception of the Gorilla); (*c*) the so-called "inner head," which arises chiefly from the ligaments covering the bases of the index and middle metacarpal bones, and is inserted into the ulnar sesamoid of the thumb—this is the *adductor obliquus* (a^1ob), and (*d*) the "interosseus primus volaris" of Henle (f^1u), a small muscular slip arising from the extreme base of the first metacarpal bone, and inserted into the ulnar sesamoid of the thumb—this, as von Bischoff has shown,[2] is the *true ulnar, or inner head of the flexor brevis pollicis.* The short muscles of the human thumb consist, therefore, of an abductor (abd^1), an opponens (op^1), a two-headed flexor brevis $(f^1r$ and $f^1u)$, and an adductor, the latter comprising three parts—(1) a *slip* attached to the radial sesamoid bone of the thumb (a^1a), (2) *adductor obliquus* (a^1ob) = the so-called "deep head of flexor brevis," and (3) *adductor transversus* (a^1tr), = "adductor pollicis" (see Plate III. fig. 1); the two latter are separated by the radial artery where it ends in the deep palmar arch. To use Professor Parker's words—"In adopting these names I feel like one who has struggled out of a quagmire of obstructive terms on to something like a raised causeway."

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[1] These letters signify *adductor primi aberrans.* In my paper on the "Morphology of the Short Muscles of the Little Finger," *Jour. of Anat. and Phys.*, vol. xx. p. 648, 1886), I have used the letters a^5a to indicate an adductor which has wandered to the ulnar side of the proximal phalanx of the little finger. As the adductors (or contrahentes) should typically adduct the digits towards a line drawn through the medius, such an insertion is evidently aberrant. I have found (in the dissecting-room of Trinity College, Dublin) a segmentation of the adductor pollicis inserted into the radial side of the index finger, also a portion of the adductor hallucis inserted into the base of the proximal phalanx of the second toe underneath the long flexor tendon ; this was arrested, so to speak, as it was creeping across from the fibular to the tibial side ; I should designate both of these muscles by the letters $a^2a.$

[2] *Op. cit.*

With regard to the hallucial muscles, I cannot do better than quote the following table from Professor Cunningham : [1]—

Flexor brevis pollicis—	Flexor brevis hallucis—
(a) Radial head,	(a) Tibial head,
(b) Interosseus primus volaris.	(b) Fibular head.
Deep or ulnar head of flexor brevis pollicis.	Adductor obliquus hallucis.
Adductor pollicis.	Adductor transversus hallucis (i.e., transversalis pedis).

Before describing the thumb muscles it is necessary to mention that there is (apparently) in all the anthropoid apes, a sesamoid bone (*radial sesamoid*) in the tendon of the extensor ossis metacarpi pollicis. I have found it in the three that I have dissected (Chimpanzee, Orang, and Gibbon). It generally articulates with the scaphoid near the tuberosity, and is connected by ligament to the trapezium. It is noticed by Hartmann[2] in the Gorilla, Chimpanzee, and Orang ; and by Vrolik[3] in the two latter anthropoids.

In the Chimpanzee the abductor pollicis arises from the anterior annular ligament and from the radial sesamoid, and is inserted (as in man) into the radial side of the base of the proximal phalanx of the thumb. The opponens arises from the radial seasmoid, from the trapezium, and from the anterior annular ligament ; it is inserted as in man. Flexor brevis (radial head) is a strong bundle of fibres arising from the anterior annular ligament, and inserted with the abductor. (In both hands of the specimen dissected (a young female), no sesamoid bones were developed in connection with the insertions of the thumb muscles.) The inner head of flexor brevis is represented by a sharply-defined glistening fibrous band, which arises from the extreme base of the thumb metacarpal, and is inserted with the adductor into the ulnar side of the base of the proximal phalanx of the thumb. The adductor pollicis arises from a fibrous band, which passes from the head of the ring metacarpal to the base of the middle metacarpal, and from the ligaments over the bases of the index and middle meta-

[1] *Op. cit.*, p. 137.
[2] *Op. cit.*, pp. 171, 172.
[3] *Recherches d'Anat. Comp. sur le Chimpansé*, Amsterdam, 1841, pp. 14, 20.

slender slip to the ungual phalanx. Adductor obliquus and adductor transversus are united (as in the Orang), and form a flattened triangular muscle, which arises from the proximal half of the third metacarpal bone, and from the ligaments at the bases of the second and third metacarpal bones. It is inserted (a) into the distal four-fifths of the shaft of the metacarpal bone of the thumb on its ulnar border; (b) into the ulnar sesamoid bone of the thumb and the adjacent part of the first phalanx; and (c) into the base of the ungual phalanx by a slender aponeurotic slip.

It will be seen from this description that the Gibbon departs furthest from the human type. This animal is remarkable in possessing a double opponens (from the flexor brevis and from the adductor); it shows a noteworthy example of how the insertion of the muscles may wander,—the radial head of flexor brevis having wandered from its primitive position at the base of the proximal phalanx both in a proximal and distal direction, and extending in an almost unbroken sheet from the ungual phalanx to near the base of the metacarpal bone;—the adductor has wandered in an almost precisely similar way on the ulnar side of the thumb. The pollicial muscles of the Gibbon differ from man (1) in the proximal position of the adductor; (2) in the part insertion of the adductor into the metacarpal bone; (3) in the prolongation of two of the muscles to the ungual phalanx; and (4) in the greater relative development and more palmar position of. the true ulnar head of flexor brevis pollicis. The Orang differs from man chiefly in its very feeble opponens. This weakness of the opponens has been noticed by Church.[1] The opponens is very human in its characters in the other two apes. The ulnar head of flexor brevis is less developed in the Orang than in the Gibbon, but is still large in comparison with the " interosseus primus volaris " of man, and much more palmar in position than the latter muscle. In the Chimpanzee all the muscles are excessively human, but the ulnar head of flexor brevis has suffered a still further reduction than in man, being here reduced to the above-mentioned fibrous rudiment, and (as in the other two anthropoids) the fasciculus of fibres which passes from the adductor obliquus to the radial sesamoid bone $(a^1 a)$ is.

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[1] " On the Myology of the Orang Utang," *Nat. Hist. Review*, p. 83.

wanting; this fasciculus is very rarely absent in man. In Professor Hartmann's figure of the palmar muscles of the Gorilla this slip appears to be present, but was evidently absent in the specimen from which Professor Macalister's figure was taken.[1] It is figured by Duvernoy, who calls it " court fléchisseur du pouce," and describes it as arising from the palmar surface of the third metacarpal bone (p. 107). In von Bischoff's specimen, as the hand was injured by excessive hardening in spirit, he could not observe the thumb muscles accurately.[2] He makes no mention of it. This origin, from the " third metacarpal bone," is evidently the slip in question; it is well developed in some of the lower monkeys, and I have seen and described it in *Macacus nemestrinus* and *Cynocephalus anubis.*[3]

Professor Hartmann has noticed in *Hylobates albimanus* the insertion of the adductor into the metacarpal bone, as I have seen it in *H. agilis.* Von Bischoff does not mention any metacarpal insertion in *H. leuciscus:* in his memoir on the Gorilla, however, he mentions that Professor Langer found a "second opponens" in the hand of an Orang, and von Bischoff regards this "adductor opponens" as a peculiar speciality of the Orang (p. 17). Vrolik[4] describes a slip from the radial head of the flexor brevis to the ungual phalanx in the Chimpanzee. I did not find this in either hand of my specimen, although, as above mentioned, it occurred in the Gibbon. The fibrous rudiment of the inner head of flexor brevis in the Chimpanzee does not appear to have been noticed by any author. Champneys describes an "interosseus volaris primus of Henle" in the Chimpanzee in the following words:—" It rose from the radial corner of the os magnum, and from the ligaments covering it; not from the metacarpal directly, as in man."[5]

I believe that I am justified in saying that the muscle here described is merely a slip of the adductor obliquus pollicis, and has nothing to do with the real " interosseus primus volaris " or deep head of flexor brevis pollicis. Bischoff, indeed, describes

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[1] *Op. cit.,* pl. xxix. fig. 8.

[2] *Beiträge zur Anatomie des Gorilla München,* 1879, p. 16.

[3] Brooks, *Jour. of Anat. and Phys.,* vol. xx. pp. 653, 654; see also pl. xxi. fig. 5, a^1a.

[4] *Op. cit.,* p. 20.

[5] *Jour. of Anat. and Phys.,* vol. vi., Nov. 1871, p. 188.

the true inner head of flexor brevis pollicis as arising "more deeply" (than the outer head) "from the trapezoid, os magnum, and their ligaments,"[1] in Cercopithecus, Macacus, Pithecia, and Hapale. In a former paper I have stated that I could not find a true ulnar head of flexor brevis either in Hapale or in *Macacus nemestrinus*. Although most unwilling to differ from so great an authority, I cannot regard the muscles, as above defined by von Bischoff, as parts of the flexor brevis at all. The typical condition of a flexor brevis (whether belonging to the thumb or any of the other digits) is a muscle arising from the base and proximal half of the shaft of a metacarpal bone, and dividing into two slips, which are inserted into the radial and ulnar sides of the base of the proximal phalanx of the same digit; this is well seen in most marsupials. I also believe that while the adductor pollicis very frequently wanders into the domain of the flexor brevis, often functionally replacing the ulnar head of that muscle, the latter shows no tendency to retaliate, but retains its primitive position on the shaft of the metacarpal bone. I have seen many instances of muscles overlapping and dwarfing others, but I have never observed a muscle burrowing, as it were, under another, except in the case of the muscles which pass under the long flexor tendons, and it appears to me that there is a mechanical difficulty in the way of a muscle extending its origin in such a manner.

The size and position of the true inner head of the flexor brevis pollicis is very remarkable in the Orang and the Gibbon. In both of these anthropoids it is relatively palmar in position, and can be seen without reflecting the adductor obliquus. Von Bischoff describes it as "very weak" in the Orang, and as "pressed into the deep" in both these animals.[2] It has also retained, in a marked degree, its primitive position on the shaft of the metacarpal bone (from which most of its fibres arise), while the radial head of flexor brevis (f^1r) has, on account of its more lateral position, followed the general rule of marginal muscles, and extended its origin upwards to the carpus.

Nervous Arrangements.—In all three animals the abductor, opponens, and radial head of flexor brevis pollicis are supplied

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[1] *Beiträge zur Anat. des Hylobates leuciscus*, p. 19.

[2] *Beiträge zur Anat. d. Hylobates leuciscus*, p. 19.

by the median nerve, and the adductor pollicis by the deep
division of the ulnar. In the Orang the true ulnar head of
flexor brevis pollicis is supplied by the ulnar, while in the
Gibbon the same muscle is supplied by the median. This is
an additional instance of how the nerves to muscles may vary
near the confines of their distribution. The absence of any
of the twigs, from the ulnar to the *outer* head of flexor brevis
(so often seen in man), taken in conjunction with the absence
of the slip (a^1a), appears to bear out the theory that I have
advanced, that the slip (a^1a) has acted as a bridge, and carried
the ulnar nerve radialwards.[1]

The following was the arrangement in both feet of a young
female Chimpanzee that I had the opportunity of examining :—
The abductor hallucis did not differ in any way from the same
muscle in man ; I did not find the accessory origin from the in-
ternal cuneiform, which is described by Vrolik, and is sometimes
present in man. Flexor brevis hallucis had two subequal
heads, the tibial slightly the larger. It arose from the liga-
ments covering the middle and internal cuneiform bones, and
from the tendon of the tibialis posticus. Adductor transversus
was separated by a small interval from adductor obliquus; it
arose from the ligaments covering the metatarso-phalangeal
articulations of the ring, middle and index fingers, from the head
of the index metatarsal bone, and from the fascia over the in-
terosseous muscles. It was inserted partly into the phalanx,
and strongly inserted into the anterior half of the fibular border
of the metatarsal of the hallux. The adductor obliquus arose
from the bases of the index and middle metatarsal bones, and
from the sheath of the peroneus longus; at least half of its
fibres were inserted into the shaft of the first metatarsal, on the
plantar side of the adductor transversus, the remainder into the
fibular side of the base of the proximal phalanx of the hallux.
In the foot of another specimen (a male between three and four
years of age) the adductor obliquus and transversus were united
to form a single fleshy mass. Comparatively few of the fibres
were inserted into the metatarsal bone, the greater number
being attached to the base of the proximal phalanx, and a

[1] Brooks, "Variation in the Nerve Supply of Flexor Brevis Pollicis, *Jour. of Anat. and Phys.*, vol. xx. p. 643.

slender tendon being prolonged to the fibular side of the ungual phalanx (see Plate III. fig. 3).

In the foot of an Orang I found the hallucial muscles disposed as follows:—The abductor hallucis arose from the os calcis only, having no origin from the annular ligament. It formed a rounded fleshy belly, much more isolated from surrounding parts than in man, and relatively much more slender. The opponens hallucis was inserted into the whole length of the tibial border of the metatarsal of the hallux from base to neck. The anterior two-thirds of the fibres were inseparable from the tibial head of flexor brevis; the posterior third formed a somewhat detached bundle, arising from a cartilaginous nodule in the tendon of the tibialis posticus; they crossed the two tendons of the tibialis anticus, and were inserted rather more on the dorsum of the metatarsal than the other fibres. The flexor brevis hallucis arose from the ligaments of the first metatarso-phalangeal articulation, and from the sheath of the peroneus longus; it divided close to its origin into two heads, of which the tibial was the larger, being to the fibular about as 4 to 1. The inner and outer heads were inserted on the tibial and fibular sides of the base of the proximal phalanx respectively; the fibular head was joined near its insertion by an accessory slip from the shaft of the first metatarsal. The adductor obliquus arose from the bases of the second and third metatarsal bones, and was inserted with the fibular head of flexor brevis. A small nodule of cartilage, representing the sesamoid bone, was found in their tendon of insertion. The adductor transversus arose from a thickened band of fascia, which stretched from the head of the index-metatarsal to the articulation of the middle metatarsal with the tarsus; a few fibres arose directly from the head of the second metatarsal. A small slip was inserted into the head of the first metatarsal, the rest joined the adductor obliquus. It was a flat, triangular muscle, lying adjacent to the adductor obliquus, but marked off from it by a plane of connective tissue. A portion of the adductor obliquus (inseparable at its origin from the rest of the muscle) ended in a rounded tendon, which passed between the two heads of the flexor brevis, and, running along in a well-marked sheath in the middle line of the digit, was inserted into the base

of the ungual phalanx. It took the place of the absent long flexor tendon. This peculiar muscle has been noticed in the Orang by Owen (*Proc. Zool. Soc.*, vol. i. p. 71), and von Bischoff found a similar condition in the hand of one of these animals. The segmentation of all these muscles was remarkably distinct, as the tough fascia on the deep surface of the flexor tendons, which forms such a well-marked feature both in the Orang's hand and foot, sent septa between them, so as to completely isolate each muscle from its neighbours. This shows a great deviation from Ruge's specimen, in which the entire flexor brevis and adductor formed a single muscular mass—"welche keine natürliche Grenze zwischen ihren Bestandtheilen erkennen lässt."[1]

In the Gibbon the abductor hallucis appeared at first sight to resemble the same muscle in man, but on raising it out of its bed a considerable number of its deeper fibres were seen to separate close to its origin, so as to form a distinct muscle, which ended in a strong tendon inserted into the base of the metatarsal of the hallux; a sesamoid bone was developed in the tendon, and the tendon of the extensor ossis metatarsi hallucis (a segmentation of the tibialis anticus) was slightly blended with it at its insertion. I found nothing in the least resembling this condition in the Orang or in either of my two Chimpanzees, and I cannot find any account of a similar muscle in the Gorilla. Church,[2] however, describes the insertion of a few fibres into the metatarsal in the Orang. With this exception I have not found any account of such a muscle; no instance, as far as I am aware, occurs in the numerous mammalian feet described by Professor Cunningham.[3] This is remarkable, as a similar segmentation of the corresponding muscle on the fibular side of the foot into abductor minimi digiti proper and abductor ossis metatarsi minimi digiti (so commonly found in man) is widely distributed. This remarkable muscle in the Gibbon will naturally be termed *abductor ossis metatarsi hallucis*. The flexor brevis hallucis arose from the proximal fourth of the shaft of the first metatarsal bone, and from the ligaments at the base of that bone. The two heads were more nearly equal than in the

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[1] " Zur vergleichenden Anat. der tiefen Muskeln in der Fusshohle," *Morph. Jahrb.*, bd. iv., 1880, p. 655, and taf. xxxv. fig. 54.

[2] *Nat. Hist. Review*, p. 91, Jan. 1862.

[3] *Zoology of the Challenger*, part xvi.

Orang, the tibial head being to the fibular about as 3 to 2. Both heads arose in common by a pointed fleshy and tendinous origin, and had no adhesion to the adductor obliquus. The two heads were inserted into the sesamoid bones at the fibular and tibial sides of the base of the proximal phalanx respectively, the tibial head also sending some fibres directly into the phalanx, and other fibres joining the tendon of the abductor. Adductor hallucis was very powerful, and the two parts (obliquus and transversus) were completely fused. It arose from the second, third, and fourth metatarso-phalangeal articulations, from the heads of the middle and ring metatarsals, from the fascia over the interosseous muscles, and from the bases of the second, third, and fourth metatarsal bones. A few of the fibres, dorsally situated, were inserted into the head and neck of the first metatarsal bone, others into the capsular ligament and continued to the phalanx; the greater number of the fibres were inserted into the sesamoid bone. At the fibular side of the articulation a feeble tendon passed into the base of the ungual phalanx, and a slender slip crossed the long flexor tendon on its plantar surface, and was attached to the sesamoid on the tibial side of the metatarso-phalangeal articulation of the hallux.

Nervous Arrangements.—In both feet of the female Chimpanzee, and in the Orang and Gibbon, the hallucial muscles were supplied as in man: the abductor and flexor brevis by the internal plantar, and the adductor by the deep branch of the external plantar. The opponens hallucis in the Orang, being a segmentation of the flexor brevis, was supplied, as we should naturally expect, by the internal plantar. In the Gibbon the abductor hallucis received two nerves, the upper one of which, after supplying it with some twigs, pierced it to end in the abductor ossis metatarsi hallucis. In the male Chimpanzee the nerve to the flexor brevis from the internal plantar gave a strong twig to the adductor hallucis, the latter muscle also receiving its usual nerve from the external plantar. Professor Cunningham has described a similar arrangement of the nerves in the foot of a Chimpanzee,[1] and I have recorded two cases of a similar variation occurring in the human foot.[2]

[1] *Op. cit.*, p. 115.
[2] *Jour. of Anat. and Phys.*, vol. xxi. p. 575.

With regard to the abductor hallucis but little remains to be added to what has been already said; in the Chimpanzee it appears to resemble the corresponding muscle in man in every particular. In the Gorilla it appears to differ from its homologue in the human subject only in its greater relative development, as far as I can judge from the works of Duvernoy, Macalister, and von Bischoff. In the Orang, Church found the abductor " chiefly differed from that of man in the large size of its origin from the annular ligament";[1] in my specimen I found that it *differed* from man in being *without* origin from the annular ligament and in its relatively feeble development. Sir Richard Owen,[2] however, found it powerfully developed in the Orang.

The homologue of the opponens pollicis of the human thumb, *i.e., a muscle derived from the tibial head of the flexor brevis hallucis inserted into the metatarsal bone of the great toe,* appears to be present only in the Orang; but in all the anthropoids some fibres of the adductor transversus (and sometimes of the adductor obliquus also) are inserted into the metatarsal bone of the hallux, constituting a *second opponens,* corresponding to the " adductor opponens" described by von Bischoff and Langer in the hand of the Orang, or to the condition (Pl. III. fig. 5) in the hand of *Hylobates agilis.* These fibres have been described as " opponens hallucis" by many authors, but unless the term is clearly defined the use of it leads to a misconception; for while the opponens hallucis in the Orang (fig. 5, op^1f) is an important hand-like character, the " adductor opponens" is distinctly a foot character, and occurs as a variety in the foot of man.[3] It appears only as an aberration in the hands of some Gibbons and Orangs. In his work on *Hylobates leuciscus,* von Bischoff says:—

" Einen *opponens hallucis* d. h. einen von den Fusswurzelknochen entspringenden und sich an den lateralen Rand und die untere Fläche des Os metatarsi I ansetzenden, von dem adductor und lateralen Kopf des Flexor brevis hallucis verschiedenen Muskel, habe ich unter den Affen nur beim Orang und Macacus gefunden, als eine auffallende Eigenthümlichkeit dieser beiden Affen" (p. 39).

[1] *Op. cit.,* p. 91.
[2] *Proc. Zool. Soc.,* vol. i. p. 71.
[3] Macalister, quoted in Quain's *Anatomy,* 9th edition, vol. i. p. 264.

The definition given here seems to refer rather to the "adductor opponens" than to the homologue of the opponens pollicis (op^{1}f).[1] In the foot of a specimen of *Macacus nemestrinus* I could not find an opponens hallucis of any description (von Bischoff's Macaque was probably *M. cynomolgus*). In his work on the Gorilla (published nine years later) he appears to have modified his views, for he exclaims—

"Nur beim Orang finde ich mit Cuvier, Owen, Huxley, und Langer einen opponens hallucis" (p. 32).

W. S. Church, writing in the year 1862, described the flexor brevis hallucis in the Orang as follows:—

"It arose from the internal cuneiform and the plantar fascia, and possessed two small bellies, the external of which was inserted into the first phalanx, the internal into the metatarsal of the hallux. In the Magot the inner belly formed a separate muscle, very much resembling an interosseous muscle, it arose from the external cuneiform bone, and was inserted into the sesamoid bone on the fibular side of the hallux."[2]

There is but little doubt from this description that Church saw the opponens hallucis, but did not recognise its importance, or name it, as Huxley did two years later. The unfortunate confusion between "internal" and "external" which appears in the above quotation renders any definite conclusion very difficult.

The insertion of part of the adductor into the metatarsal bone of the hallux has been described by Duvernoy[3] in the Gorilla, by Church[4] in the Orang, and by Champneys[5] in the Chimpanzee. These authors, however, do not speak of this metatarsal insertion as an opponens hallucis. This insertion in the Chimpanzee is very graphically shown in one of Vrolik's figures, part of which I have reproduced (Pl. III. fig. 2); Vrolik, however, makes no mention of it in his text, and it is probable that he mistook the muscle for the first dorsal interosseous, as Hartmann[6]

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[1] In page 63 of the same work von Bischoff gives a much more correct definition :—"Fur den Orang und Macacus ist noch hervorzuheben, dass sie an der grosse Zehe einen Opponens, d. h. einen von den Fusswurzelknochen an den medialen Rand des ersten Metatarsusknochen gehenden Muskel besitzen, der diesen ihren Fuss der Hand noch ähnlicher macht."

[2] *Op. cit.*, p. 92.
[3] *Op. cit.*, p. 114.
[4] *Op. cit.*, p. 93.
[5] *Op. cit.*, p. 204.
[6] *Anthropoid Apes.* In fig. 55, p. 178, the metatarsal insertion of the adductor transversus is lettered "first dorsal interosseous."

has certainly done. The muscle is not only entirely separate from the first dorsal interosseous, but its fibres have a totally different direction and are on a different plane; moreover, it is inseparable from the part of the same muscle which is inserted into the proximal phalanx of the hallux, and in some cases it cannot be separated from the adductor obliquus also. The peculiarity of the first dorsal interosseous muscle in both hand and foot of apes[1] does not appear to have received the attention it deserves. The pollicial and hallucial heads of this muscle have suffered a great reduction in these animals. It is most human in its character in the hands of the Chimpanzee and Orang; but in the feet of these two anthropoids, and in the hand and foot of the Gibbon, the pollicial (hallucial) origin is rudimentary or absent. In the Chimpanzee it arises from the extreme base of the metatarsal of the hallux (Pl. III. fig. 3, abd^2); in the Orang it takes origin from the internal cuneiform bone (which in this ape is placed at a different angle to the remaining cuneiforms, thus resembling the trapezium in the hand). In the hand of the Gibbon (Pl. III. fig. 5, abd^2) it arises from the trapezium and base of the thumb metacarpal; in the foot of the same animal it is a single-headed muscle, arising entirely from the tibial side of the index metatarsal bone.[2]

The flexor brevis hallucis in the Chimpanzee approaches its homologue in man very nearly in the almost equal size of its fleshy bellies, in the inclination of its origin towards the fibular side of the foot, and in the absence of any fibres arising from the metatarsal bone of the hallux; as in man, some of the fibres of the tibial head join the tendon of the abductor. Champneys found a very complex condition of this muscle in his Chimpanzee,[3] differing widely from the simple and man-like condition in my specimens. In the Orang and the Gibbon the flexor brevis departs much more widely from man, and presents noteworthy

[1] I have noticed this peculiarity in the lower apes also, particularly in the hand of *Cynocephalus anubis.*

[2] The insertion of the abductor indicis in both hand and foot was (as usual) into the base of the proximal phalanx, and (through the extensor tendon) into the base of the ungual phalanx. I could not find any separate tendon inserted into the ungual phalanx, as described by Huxley, under the name of "abductor tertii internodii secundi digiti."—*Medical Times and Gazette,* vol. i. p. 647, 1864.

[3] *Op. cit.,* p. 203.

differences in these two animals. In the Orang the bellies are very unsymmetrical, and, through the ligaments, incline towards the cuboid bone, foreshadowing (in the latter respect) the condition in the Chimpanzee and in man. In the Gibbon the bellies are subequal; they are united for the proximal half of their length, arise largely from the shaft of the metatarsal bone, and the fibres are all directed parallel to the axis of the first digit, showing no inclination to the fibular side of the foot. Von Bischoff[1] and Ruge[2] found the fibular belly of flexor brevis completely united with the abductor in the Orang, but Owen[3] seems to have found it separate in his specimen. In the Gorilla the descriptions given by von Bischoff and Duvernoy show that the fibular head of flexor brevis is more reduced than it was in the Orang that I dissected. Von Bischoff found it weak and deeply placed in his specimen,[4] and he points out its identity with the following muscle described by Duvernoy:—

"On pourrait considérer comme l'analogue d'un inter-osseux plantaire un faiseau musculeux qui s'attache le long de la face externe et palmaire du métatarsien du pouce et qui va se terminer au tendon de l'adducteur."[5]

In contrasting the muscles of anthropoids with those of man von Bischoff lays some weight on the condition of the adductors of the pollex and hallux, classifying them into those in which the obliquus and transversus are united and those in which they are separate. In one of my Chimpanzees the two muscles were separated by an interval, in the other they were united into one mass. The literature of the subject shows that similar variations are met with in different specimens of the other anthropoids, and they are known to occur in the human subject. Professor Flemming, of Kiel, writing on the muscles of the human thumb, says:—

"Die Trennung dieser Portion D" (i.e., adductor obliquus), "vom

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[1] Von Bischoff, *Hylobates*, p. 38, " Beim Hylobates ist er sehr schwach, und beim Orang konnte ich ihn nicht von dem hier ganz besonders starken Adductor obliquus trennen." See also p. 62.

[2] *Loc. cit.*

[3] *Loc. cit.*

[4] Bischoff, *Gorilla*, p. 31.

[5] Duvernoy, *loc. cit.*, p. 116.

Adductor ist also schon rein myotomisch genommen ganz künstlich, sie kann nur durch einen kühnen Schnitt bewerkstelligt werden."[1]

Every practical anatomist will recognise the correctness of this observation; nevertheless cases occur in which the two muscles are quite distinct. In a hand, in the dissecting-room of Trinity College, Dublin, I found the adductor transversus widely separated from the adductor obliquus, and in several human feet I have seen the "transversus pedis" with an extensive origin from the fascia which covers the interosseous muscles, and with its border adjacent to the adductor obliquus; this condition can be well studied if a dissection be made from above by removing the three middle metatarsal bones; it is interesting in connection with Ruge's embryological observations,[2] showing a partial persistence of the embryonic condition. From these considerations it appears to me that the separation or fusion of the two portions of the adductor is not a point of much morphological importance.

EXPLANATION OF PLATE III.

Fig. 1. Muscles of Human thumb (after von Bischoff). abd^1, abductor pollicis; op^1, opponens pollicis; f^1r, radial, and f^1u, ulnar heads of flexor brevis pollicis; a^1a (adductor primi aberrans) = slip of adductor obliquus, which passes to be inserted into radial sesamoid bone and is prolonged to base of proximal phalanx of thumb; a^1ob, adductor obliquus; a^1tr, adductor transversus; (f^1u lies normally under cover of a^1ob, but is dragged into view by a black thread in the figure).

Fig. 2. Dorsal view of hallucial muscles of a Chimpanzee (after one of Vrolik's figures). v, prolongement de la veine crurale que s'enfonce dans le pied." (The following are not lettered in the original.) a^1ob, adductor obliquus hallucis; a^1tr, adductor transversus hallucis; abd^2, abductor indicis.

Fig. 3. A similar view of the foot of a male Chimpanzee. a^1, abductor hallucis (add. transv. and add. obliq. were fused into a single mass in this case); part of the muscle, a^1op, is inserted into the metatarsal bone; another portion ends in a tendon, t, which is inserted into the ungual phalanx. The extensor tendons of the hallux have been

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[1] " Über den *Flexor brevis* pollicis und hallucis des Menschen." *Anat. Anzeiger*, II. Jahrgang (1887), Nr. 3, p. 71.

[2] "Processes in the Development of the Muscles of the Human Foot," *Morph. Jahrb.*, 1878, p. 132.

drawn aside by a pin, and the joint, *j*, between the phalanx and the metatarsal bone opened in order to demonstrate more clearly the metatarsal insertion of the adductor; *ebd^1*, first slip of extensor brevis digitorum. The vein, *v*, passes between the two heads of the first dorsal interosseous muscle, *abd^2*.

Fig. 4. Foot of Orang. *abd^1*, abductor hallucis; *op^{1}f*, opponens hallucis; *elh*, extensor longus hallucis; *ebd^1*, first slip of extensor brevis digitorum, which, in this specimen, presented the great peculiarity of being inserted into the metatarsal bone instead of the phalanx; *ta*, tibialis anticus; *ta^1*, ext. ossis metatarsi hallucis; *tp*, tibialis posticus.

Fig. 5. Hand of Gibbon (dorsal view). *abd^2*, abductor indicis; showing great reduction of pollicial origin; *a^1*, abductor pollicis, showing powerful insertion into metacarpal bone of thumb, and a tendon, *t*, prolonged to ungual phalanx.

(Figs. 3, 4, and 5 are from the author's dissections.)

NOTES ON MUSCULAR ABNORMALITIES. By Thomas Dwight, M.D., *Parkman Professor of Anatomy at Harvard University, U.S.A.*

Absence of Flexor Carpi Radialis.—This observation, which I believe is unique, was made in 1876, at the Medical School of Maine, but has never been published. The abnormality occurred on the right side of the body of a muscular young man which I had used for my lectures on myology. The *flexor carpi radialis* was entirely wanting. No trace of anything representing it was to be found at the places of its insertions into the metacarpus. A small pale muscular belly arose from the anterior border of the tendon of the *supinator longus*, about one inch above the styloid process, and (becoming tendinous) passed through a separate sheath near the surface of the annular ligament. The radial artery lay between this extra muscle and the *supinator longus*. I expected to find that this slip took the place of the absent muscle, but it was traced into the *abductor pollicis*. The *palmaris longus* was very strong, its muscular portion extending more than half-way down the fore-arm. Extra muscular slips are not uncommon in this region, as is well known, but I have found no description of one precisely resembling this one. The question arises whether it can be held to represent the *flexor carpi radialis*. The only point in favour of such a view is its position and relation to the artery just above the wrist, but the much more important considerations of its origin and insertion are against it.

Duplicity of the Vastus Externus.—Professor Macalister mentions the fact that this muscle may be double, but gives no details. Testut speaks of it as a very rare condition. Mr Knott writes as follows:—" The vasti have sometimes been found bilaminar, and this is, I think, more frequent than is usually supposed. I have noted five cases of this arrangement in the internal and three in the external muscle, and also met with many others of which I have made no record." In confirmation of this view may be quoted Henle's description of the normal anatomy of the muscle. Mr Williams, in his elaborate

account of the *quadriceps*,[1] shows that the lower anterior edge of the *vastus externus* consists of two tendinous laminæ, between which run nerves and vessels, and which can very easily be accidentally separated in dissection, so that the muscle may be split into two layers. I believe that it is by no means very uncommon to find two layers in this region that do not owe their separate existence to dissection. There is, however, another form of duplicity of this muscle that is due to its arising in two layers. The only case on record that I know of is Gruber's, observed in 1847–8, and published in Virchow's *Archiv*, Bd. lxxxii., 1880. One head arose from the outer side of the great trochanter, from the line to the *linea aspera*, from that line, and from the outer side of the femur half-way down. The other head arose from the upper part of the anterior inter-trochanteric line, from the front of the greater trochanter and from the front of the femur. It was uncovered by the first head in the upper part, but passed under it below and united with it. It was quite distinct from the *crureus*.

I observed two cases in January 1886, which resembled this one in having a double origin, but differed from it in having one head more or less closely connected with the hip-joint.

1st Case. Male. White. Left side.—A tendinous band, about one-third of an inch broad and four inches long, arose from the anterior surface of the capsule of the hip-joint a little below the inferior spinous process of the ilium, and joined the deep fascia of the *tensor vaginæ femoris* near the lower end of the muscular fibres. One inch and a half from its origin it gave off a slender tendon, which two and a half inches lower down became muscular, and joined the anterior surface of the *vastus externus* at about the middle of the thigh.

2nd Case. Male. White. Right side.—The origin from the *linea aspera* was shorter than usual. The important peculiarity is that a part of the muscle sprang from a tendinous band attached to the anterior inferior spine of the ilium, and apparently representing the inner limb of the Y ligament. The lower part of this was muscular, and joined the anterior edge of the *vastus externus*.

Mr Morris, in his excellent work on the joints, describes

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[1] *Jour. Anat. and Phys.*, vol. xiii. p. 204, 1879.

(p. 326) "a tendinous band closely blended with the surface of the capsule stretching between the upper extremity of the tendon of origin of the *vastus externus* and the long tendon of the *rectus*." If this structure is, indeed, of constant occurrence both these cases may be explained as slight variations, but though I have looked for it many times, and have seen the arrangement described by Mr Morris beautifully evident, I cannot agree with him that it is the usual one. It seems to me more common to find a process of fascia passing from the front of the capsule to the deep layer of the fascia lata below the *tensor vaginæ femoris*, and having no connection with the *vastus*.

It occurred to me as possible that in the earlier part of life the muscle might have a higher origin. To determine this, I caused the bodies of some ten or more infants to be examined, but nothing confirmatory was found. I examined myself several fœtuses, mostly of the latter half of pregnancy, but with a negative result, excepting that in one of about four months the *vastus* seemed to encroach on the capsule.

Interclavicularis anticus digastricus.—This very rare abnormality was observed in the winter of 1885-6, on the body of a white woman. The greater part of the clavicular portion of the *pectoralis major* was wanting on both sides. There was only a narrow slip arising at the junction of the outer and middle thirds of the clavicle. This was intimately connected with the deltoid. A vacant space about three inches wide was left between it and the sternal portion. Both the deficiency in the pectoral and the two halves of the abnormal muscle were very symmetrical. The latter sprang from the front of each clavicle by an origin about one inch and a half broad, the outer end of which was covered by the inner border of the clavicular portion of the *pectoralis major*. The outer parts were muscular, and were united by a median tendon about two inches long, which crossed the sterno-clavicular joints and lay in front of the sternum. Some of the superior fibres of the sternal portion of the *pectoralis major* sprang from this tendon.

Professor Gruber[1] has described two cases of this abnormality. It is important to notice that in both of his, as in mine, there

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[1] Reichert and Du Bois Reymond's *Archiv*, 1865, and Virchow's *Archiv*, 1878, Bd. lxxii.

was a deficiency in the *pectoralis major*. In the first, the inner part of the clavicular portion was wanting, and the remaining slip was separated by a well-marked interval from the deltoid. In the second case, nearly the inner half of the clavicular portion was wanting, and also the upper part of the sternal portion. In both cases, as in mine, a part of the greater pectoral arose from the abnormal structure. Gruber regards this muscle as representing the union of two sterno-claviculares, one from each side. He reports in the former place an instance of a single *sterno-clavicularis*, in which nearly the whole of the clavicular part of the *pectoralis major* was wanting, and in which the upper fibres of the sternal portion were attached to the origin of the anomalous muscle. I have met with the muscle this year on the left side of a white male subject, which had on both sides a deficiency of the greater part of the clavicular fibres of the pectoral. Professor Macalister wrote in 1871 that Mr Stoker had communicated a case to him, in which the sterno-clavicular muscle coexisted with an absence of the clavicular fibres of the great pectoral. The frequency of this coincidence in the case of both simple and double sterno-clavicular muscles, and the fact that the sternal portion of the pectoral is frequently attached to them, seem to point to some intimate relation between them, and indeed I have presented this group of anomalies on account of the bearing this fact may have on the interpretation of some forms of *sternalis*.

Sternalis.—*1st Case.* Female anencephalous fœtus.—There was a deficiency in each *pectoralis major*. The upper part of the sternal portion was closely united with the clavicular portion. This upper part of the muscle arose on the left from the clavicle, the front of the manubrium, and from the cartilages of the first two ribs. On the right it sprang from the clavicle, the cartilages of the first three ribs, but not at all from the sternum excepting near the sterno-clavicular articulation. The lower portion of the muscle, separated from the upper one by an interspace which is larger on the left, arose on the left from the cartilages of the 3rd, 4th, and 5th ribs, and on the right from those of the 4th and 5th. The *sternalis* was present on both sides. On the right it ran along the inner border of the upper division of the pectoral

from the cartilage of the 4th rib to near the top of the manu-brium. On the left the muscle was divided into two parts. The lower ran upwards and slightly inwards from the cartilage of the 4th rib to that of the 3rd, and the upper one from that of the 3rd to that of the 2nd. Its lower part was external to the upper end of the lower one. Both the slips of the left side appeared, judging from a sketch which I made at the time, to partly overlap the pectoral fibres. This case was observed eleven or twelve years ago, before Mr Abraham had called attention to the frequent occurrence of this muscle in anence-phalous foetuses. Since this point was raised I have looked for it in several[1] such cases without once finding it, which is very different from the experience of Mr Abraham and Professor Shepherd. Perhaps sufficient attention has not been paid to the deficiency of a part of the great pectoral on the same side as the *sternalis* in anencephalous foetuses. Thus, of the six foetuses in which Mr Abraham found the muscle, four presented a defect in the pectoral. In two of these the defect and the *sternalis* occurred on both sides, in two others on the same side. Professor Shepherd found nine sternales in six anencephalous monsters, and eight times there was a defect of the pectoral on the same side.

I have long been of Professor Bardeleben's opinion that the *sternalis* does not always have the same significance, and that in many cases it stands in some relation to the pectoral. The question now arises whether the occurrence of a defect in the latter muscle does not predispose to an irregular arrangement of other muscular fibres in the neighbourhood, which in some cases may appear as the *sternalis*, and in others as the *sterno-clavicularis*, either single or double, in the latter case being the abnormality described above.

The following cases of *sternalis* were observed in the adult:—

2nd Case. Female. Black. Right.—Arises from sheath of rectus opposite 5th or 6th costal cartilage, about 2 inches from median line, runs upward and somewhat inward to end in fascia covering the pectoral at the level of the 2nd cartilage. Breadth about ¾ inch.

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[1] I can find no record of the number of these observations, but I think I made from four to six.

3rd Case. Female. White. Right.—A triangular muscle; begins by small tendinous bands from sheath of rectus opposite 6th cartilage, 1 inch from median line. The inner border is vertical, slightly concave, the other extends obliquely outwards. Greatest breadth 2½ inches opposite 2nd rib. At this level the outer part becomes fibrous, and ends in fascia covering the outer part of pectoral. It can be traced as a distinct structure for some distance. The inner part runs into the sternal head of sterno-mastoid. *Nerve supply* from intercostals.

4th Case. Male. White. Left.—Arises from sheath of rectus besides sternum opposite 5th and 6th cartilages, and also by (tendinous) fibres that cross the lower portion of the pectoral. Greatest breadth ¾ inch. It ends by a narrow tendon in the middle line over the manubrium.

5th Case. Male. South Sea Islander. Double.—This is in some respects a remarkable case. The cartilage of the 5th rib on the right side enlarges to inclose a foramen, and regains its proper size before reaching the sternum. The *right sternalis* began by tendinous fibres from the 7th cartilage just before its junction with the sternum. It was reinforced by others from the 6th cartilage, and by some from the surface of the sternum. It became muscular opposite the 5th cartilage, from which it received additional fibres. Opposite the 4th cartilage it expanded to an inch in breadth, and, growing broader opposite the 3rd, divided into two parts. The outer one spread out over the pectoralis, and was lost in the fascia covering it. The inner division received a minute muscular belly from the 4th cartilage, and soon became tendinous and ran to the middle line, dividing into a slender tendon which joined the sterno-mastoid of the same side, and into several bands which passed under the pectoralis major of the *opposite* side. Some of these were attached to the 2d left cartilage, and two others gave origin to a deep head of the left pectoralis major, which was soon lost in that muscle.

The left *sternalis* arose as a slender tendinous band from the fascia covering the *pectoralis major* at the lower border of the muscle opposite the 5th intercostal space, 1 inch outside of the cartilage. This ran inwards, describing a slight curve till it reached the sternal end of the 6th cartilage, where it turned

suddenly and ran up along the side of the sternum to its inser-
tion into the front of the bone at the level of the 2nd cartilage,
where it ended under cover of the right sternalis. *Nerve supply*
from a long slender nerve which entered the deep surface of
the muscle opposite the 3rd intercostal space, and which was
traced through the pectoralis major nearly to the border of the
axilla. As the subject was to be used for lectures on topo-
graphical anatomy, and as it was undesirable to open the
axilla, the nerve was left at this point to be pursued later, which
unfortunately was not done. The left nerve was smaller than
the right one. They probably came from one of the anterior
thoracic nerves.

6th Case. Male. White. Right.—Arose from pectoral fascia
over 5th cartilage, about 1 inch from median line, by a narrow
flat tendon. The greatest breadth of the muscle was less than $\frac{1}{2}$
inch. It received some fibres from the fascia at its outer edge,
and ended in the sterno-mastoid.

7th Case. Female. White. Double. *Right side*—Origin
from pectoral fascia over 5th rib, 4th cartilage, and fascia over
sternum. Insertion into right sterno-mastoid. Innervation by
3rd intercostal nerve. *Left side*—From pectoral fascia at level
of 6th cartilage to left sterno-mastoid. *Innervation* by 2nd
and 3rd intercostals.

ERRATA.—In Professor Dwight's paper on "Abnormal Spines," vol.
    xxi. p. 539, line 21, 1887, for "painful" read "fanciful." It
    should also be understood that the cervical ribs described on p.
    542 belonged to the spine which possessed the abnormal atlas.

DESCRIPTION OF A NEW FORM OF RECORDING APPARATUS FOR THE USE OF PRACTICAL PHYSIOLOGY CLASSES. By RICHARD CATON, M.D., *Professor of Physiology, University College, Liverpool (Victoria University).* (PLATE IV.)

IT is unnecessary for me to point out how much instruction the physiological student gains from experimental work done by his own hands, and how great is the difference to him between merely witnessing an experiment performed by a teacher and actually doing it himself.

The details of the experiment, the precautions to be observed, the result obtained, and the law or principle which this result sets forth, arrest the student's attention strongly if the responsibility of the experiment rests with himself. Moreover, the near contact with the actual fact leaves on his mind an impress far more exact and more lasting than he can possibly gain by the study of any mere statement of the fact, or even by witnessing its demonstration by some other person.

Of course there are only certain kinds of work which can thus be put into the student's hands. Provided a sufficient amount of apparatus is supplied, it is quite possible, in addition to the work commonly done, to give to a considerable number of students the opportunity of investigating for themselves the phenomena of vascular pressure and the functions of muscle; and though the work thus done covers only a small part of the wide field of physiological science, it gives a reality to their knowledge and an acquaintance with physiological methods which is of considerable value.

In the Liverpool laboratories we have felt for some years the need of a recording apparatus which should allow small groups of students—say six or eight men at a time—to do practical work of the kind named.

For this purpose it was necessary to provide eight revolving drums, which could be driven simultaneously at any required rate of speed.

This could easily have been supplied had we been prepared to spend a few hundred pounds.

The apparatus provided by the Cambridge Scientific Instrument Company answers the purpose well. It is constructed with the greatest care, but, unfortunately, it is costly. Moreover, it requires a gas engine to drive it, and that form of motor is not only expensive in first cost but needs the occasional attendance of an engineer. On monetary grounds, therefore, the Cambridge apparatus was quite out of the question for us, and the only course open was to devise and construct a cheap and simple apparatus for ourselves.

Various schemes were proposed, and at length one was decided upon and carried out, after being modified somewhat during construction.

The apparatus thus devised has now been in operation more than a year, and has been found to answer satisfactorily.

The first question to decide was that of the motive power to be adopted. We needed something cheap, easily managed, and not likely to get out of order.

The "Thirlmere" water motor was selected. Having in Liverpool a fairly good water pressure we found that a small Thirlmere, costing under £4, was sufficiently strong.

A long fixed table (*vide* fig. 1) in one of the laboratories was chosen to attach the apparatus to. The motor *a* was placed in a cupboard under one end of this table, as seen in the sketch (the doors are removed).

A number of metal bearings *b.b.b*, about 8 inches high, were placed at equal distances in a line down the centre of the table. These support a long steel shaft. In the course of this shaft are placed at equal distances eight coned wheels of gun metal *c.c.*, 6 inches in diameter; one of these wheels is shown in profile in fig. 2. These wheels are fixed to the steel shaft and revolve with it.

From the axis *d* of the Thirlmere motor a cat-gut band passes round the circumference of a heavy fly-wheel *e.e.*, about 30 inches in diameter, situated near the motor under the table. A small wheel *f* on the axis of the fly-wheel imparts motion to a cat-gut band, which passes through the top of the table to the circum-
ce of the wheel *g*, which is attached to one end of the shaft.

The water motor can be set agoing by turning the tap h. Its speed of revolution can also to a certain extent be regulated by this tap. As soon as the tap h is opened the motor begins to work, causing the fly-wheel and the small wheel on its axis to revolve, and the movement is transmitted to the shaft and coned wheels.

Fig. 3 is an outline sketch on a larger scale of one of the eight drums and its stand. An iron casting $i.i$, 10 inches long and 7 inches broad, standing on three feet, carries a short upright piece k and a longer upright l; an arm m projects horizontally from the latter as shown in the drawing.

Two grooves (seen on each side of n in the figure) allow the wheels o and p to sink some distance into the base-plate of the iron casting. At r a small hole in the base-plate receives the lower end of the spindle rs. The spindle also passes through an accurately drilled hole in the horizontal iron plate m; the bearings at r and m support and hold steady the spindle and the drum shown in the sketch.

An axle passing horizontally through the perpendicular pillar l carries a gun-metal coned wheel p (just like fig. 2) and a gun-metal friction-wheel o, 6 inches in diameter. A screw t with milled head passes through the pillar k, and presses with its pointed end against a small concavity in the end of the axis, which carries the wheels p and o, causing the wheel o to press against the two small wheels v and r which are situated on the spindle. These small wheels v and r have an outer rim of india-rubber; v is attached firmly to the spindle by a small screw, and can be raised or lowered; r, on the contrary, is not attached to the spindle, but moves freely upon it.

The drum and stand being placed on the table with the wheel p in a line with one of the wheels c on the steel shaft, a leathern cord is put in a figure-of-eight loop round the two coned wheels, in one or other of the three grooves which each wheel possesses.

The shaft and coned wheels upon it now being made to revolve, transmit motion to the coned wheel p, and the friction-wheel o of course moves with the latter. The screw t is now tightened until the wheel o, pressing as it revolves against v, sets the drum in motion.

The small wheel r revolves in a reverse direction on the

spindle, and is found of considerable use in keeping the friction-wheel steady.

When the class is at work four drums are placed on each side of the table; all can be driven at one time, and each at any speed desired. Speed is chiefly regulated in the following way:—If the figure-of-eight band referred to above be placed in the outermost groove of the wheel c, and in the innermost groove of the wheel p, a high velocity is imparted to the drum ; if, on the contrary, the band rests on the innermost groove of c and the outermost of p, a low speed results, and all kinds of intermediate speeds can be secured by other combinations. By raising or lowering the small wheel v further modifications of speed are obtained, and, as I have already remarked, a higher or lower speed can be given to all the drums simultaneously by allowing a greater or lesser amount of water to enter the motor.

The drums are movable, so that the table can be used for other purposes than the foregoing.

The total cost of this apparatus, including motor, water supply pipe, waste pipe, wheels, shaft, drums, and drum-stands, including also the expenditure due to faults in our plan and modifications made during construction—an important item,—was £60. I have little doubt it could be constructed for £40 by any one who, at the outset, had the knowledge which we had to acquire by experience.

The drums are not so well constructed or quite so perfectly centred as those made by the Cambridge Company, but they answer the purpose well, and excellent tracings are taken on them.

I ought to add that I received valuable aid from Mr Larkin, Demonstrator of Practical Physiology, while designing and superintending the construction of this recording apparatus.

A NEW MODEL FOR DEMONSTRATING THE ACTION OF THE MUSCLES OF THE EYEBALL. By DE BURGH BIRCH, M.D., F.R.S.E., *Professor of Physiology in the Yorkshire College, Leeds.*

FEELING the want of a model suitable for demonstrating to a class the combination of muscular actions by means of which the eyeball is moved, I devised the following simple mechanism, which was constructed by my laboratory attendant.

A wooden sphere 4 inches in diameter represents the eyeball. On its anterior surface are painted the pupil and iris, and to the posterior an elastic tube is attached. This tube, which represents the optic nerve, is made fast to a wooden support further back, and keeps the ball firmly applied against a stout iron wire ring, which acts as a socket. This ring is held in position by an arm fixed in the vertical support already mentioned. The muscles are represented by cords attached to the eyeball at their respective mean points of insertion.

The recti muscles pass backwards over pulleys in the neighbourhood of the attachment of the tube representing the optic nerve, whilst the oblique muscles pass over two pulleys, placed in a separate upright to the nasal side of the eyeball.

A set of six levers, forming a small keyboard, is placed in the lower part of the model; to these the cords are attached after passing round a second row of pulleys. On the free end of each lever the initials of the muscle supposed to be represented by it are marked. Near this end also are attached india-rubber bands stretching from the base board, by means of which the levers are retained in proper position and are caused to adapt themselves to the tension on the cords.

To render slight movements of the eye more easily perceptible, a light wooden rod can be inserted into the centre of the pupil so as to represent the visual axis. The various arrangements mentioned will be readily understood from the accompanying woodcut.

When the model is placed so that the visual axis is turned

directly forward to the horizon the muscles may be regarded as in equilibrium, and the free ends of the levers will stand in a line with each other.

The model can be used in two ways :—(1) By pressing upon one bar or several bars together a movement of the eyeball is produced corresponding to that which would be brought about by the represented muscles in the natural eye. (2) Starting from the position of equilibrium (*i.e.* with the levers in line), the eyeball can be moved with the hand directly, then the muscles which would produce that particular transposition are indicated by a depression of the corresponding lever ends, any muscles stretched in the act being indicated by an elevation of their levers.

The model is simple in construction, can be easily seen, and is well adapted for demonstrations.

ON SOME POINTS IN THE ANATOMY OF A *MEGAPTERA LONGIMANA.* By John Struthers, M.D., *Professor of Anatomy in the University of Aberdeen.* (Plates V. and VI.)

PART I.

History and External Characters.

Parts Noticed and Order.

1. History.—This Megaptera, a male, 40 feet in length, had shown itself in the Firth of Tay, off Dundee, for five or six weeks before the end of December 1883, when it was at last fatally wounded. After about a fortnight it disappeared for eight or ten days, then reappeared in the Tay, and during the three weeks before its death disported itself freely in sight of the inhabitants of Dundee, up and down the river, going up as far as the docks. The attraction to the Tay was believed to be the young herring with which the firth abounded at the time.

From the newspaper accounts of the appearance and movements of this whale in the firth, I had inferred that, although very rare on British coasts, it must be a *Megaptera longimana.* As described to me by witnesses who watched its movements, it rose out of the water seemingly for two-thirds of its length, almost perpendicularly, flapped its enormous paddles, and then fell to one side, causing great commotion in the smooth water.

This movement it was seen on one occasion to repeat three times. The movement was described as resembling the leap of a salmon, but slower. The intervals between the blowings were generally about two minutes, never more than five minutes. A stream like a spray fountain went up for, it seemed, 15 to 20 feet, at first straight up and then broke. The blow-hole part was not visible above water. When it rose ordinarily the back was seen first, then the dorsal fin; in disappearing, the dorsal fin was the last seen; neither the tail nor the paddles were shown.

When at last successfully harpooned it showed great strength and endurance for twenty-one hours, when the line parted, but it had been mortally wounded.[1] This was on New Year's morning, 1884. A week afterwards the carcase was observed by fishermen off Bervie, on the coast of Kincardineshire, floating so high as to be visible 6 miles off. It was towed into Stonehaven harbour on January 8, and beached there.

My first observations and measurements were made as it lay on its back at Stonehaven, and photographs were taken, from one of which fig. 1 is taken. On the day after it was beached, the carcase, the property of the fishermen who found it, was exposed by public sale and purchased for a large price by Mr John Woods, oil merchant, Dundee, with a view to exhibition.

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[1] Some particulars of the endurance may be interesting. After the first harpoon, which was thrown and went in at the shoulder, it swam quietly, rising at intervals of two minutes to blow, but the vapour was reddish. After a second harpoon, which was fired, took effect, it made vigorous efforts, threw the tail in the air, lashed the water furiously and darted about in different directions. Volumes of blood were now thrown up, colouring the surrounding water. It had at first to drag two six-oared rowing boats and a steam launch, and, four or five hours afterwards, a steam tug was added. With this heavy drag it swam wildly about, on one occasion rising under one of the boats and lifting one end of it out of the water. Hand-lances were driven 3 feet deep into it, and blood spouted from the wounds. Two of the harpoon lines parted, but the steam tug and the two rowing boats were dragged out to sea by the remaining line, north to near Montrose, south to near the mouth of the Firth of Forth, then north again. At daylight a 4-feet-long iron was fired into it, also a couple of marling-spikes, and a number of iron bolts and nuts. About twenty-one hours after being harpooned it showed signs of exhaustion, turning from side to side and lying level on the water, but shortly revived and again held on; in half an hour the line parted, some way south of the Bell Rock, and the whale was free. The cruelty, which one cannot but recognise, of this long chase was largely owing to deficiency in modern appliances of attack.

The carcase was removed the same night to Dundee, tugged by a rope attached to the tail.[1]

2. DISSECTION OF THE CARCASE.—After it had lain a fort-night for exhibition, I was allowed to make a dissection of the carcase, in which I was assisted by Mr Robert Gibb and Mr George Sim, of Aberdeen, and by several Dundee whale-fishers.[2] The carcase having been turned on the back, my first care was to remove a large portion of the abdominal wall, in its whole thickness, from the umbilicus to behind the anus, and of sufficient breadth to include the pelvic bones and rudimentary hind limbs. This half-putrid mass was pickled and sent on to Aberdeen to be dissected at leisure. On looking for the viscera they were found to be so decomposed as to be mostly unrecog-nisable, reduced along with the muscles to a pulp into which the whale-fishers went knee-deep. We tried to preserve the heart, but our hands went through it. Our attention was therefore directed to securing the bones, some of which came out already detached from the soft parts. The vertebræ, except those of the narrow part next the tail-fin, the sternum, ribs, and hyoid, were removed, and sent on to my macerating troughs at Aberdeen.[3]

On August 7, fully seven months after the death of the whale, I went to Dundee to complete the removal of the bones,

[1] When lifted out of the water in Dundee harbour with the steam crane, by a chain round the tail, high in the air, the tongue and some other soft parts, and the cervical vertebræ, fell out by the mouth into the water. The vertebræ were recovered. It was then placed on the belly on railway lorries, and dragged by eighteen powerful horses along the docks, and, after various mishaps, reached Mr Woods' yard, where it was placed for exhibition.

[2] I may here remark, in apology for delays and shortcomings in my observa-tions of the external characters and internal structure of this Megaptera, that everything had to be subordinated to its exhibition at Dundee and then at other towns. The dissection was not only late (January 25 and 26), but was attended by difficulties and by unusual accompaniments. When we arrived to perform it, we found that the astute proprietor had announced a special admission, adding the attraction of a band of music, and I may add we had a snow-storm which drove us off from time to time.

[3] The remains were then prepared for exhibition by the proprietor, Mr Woods. The putrid soft parts having been scooped out, and the remaining soft parts prepared with antiseptics, a wooden backbone was introduced, wooden bars supplied the place of ribs, and the body was stuffed and stitched below into proper form. The embalmed whale, thus wonderfully restored in form and much lightened, was exhibited during the next few months in various towns, first in Aberdeen, then in Glasgow, Liverpool, and Manchester, again in Glas-gow, in Edinburgh, and finally again in Dundee.

in which I was assisted by Mr Robert Gibb, Aberdeen, and Dr Greig, junior, Dundee. The blubber in being cut in pieces was seen to average about 3 inches in thickness and was in a fair state of preservation. The skull and remaining bones were sent on to Aberdeen, the paddles entire, so that I could dissect them carefully. The skeleton was presented by Mr Woods to the Dundee Museum, where it will be finally placed.

3. MEASUREMENTS—

	ft.	in.
Length, from point of lower jaw to cleft of tail, straight, ...	40	0
Pectoral fin, length along lower border, . .	12	0
„ greatest breadth, . . .	2	8½
Dorsal fin, height of fin proper, . . .	0	7
„ height of entire elevation. . .	0	11
„ distance from cleft of tail, . .	12	4
Tail fin, width between the tips, . . .	10	6
„ extreme width, straight, . . .	11	4
„ greatest antero-posterior breadth, .	3	0
Mammillary pouch, in front of anus, . .	2	0
Projection of lower jaw beyond upper, . .	1	1
Point of lower jaw to angle of mouth, straight,	9	4
Same to below angle of mouth, along the curve, ...	10	4
Point of lower jaw to pectoral fin, . . .	14	1
Eye to eye, centre of, over the top, . .	7	10
Distance of latter line behind blow-holes, .	1	2
Ear-hole behind posterior canthus of eyelids, .	1	5
Whalebone, largest plates, length, . . .	1	8
„ largest plates, greatest breadth, .	0	5

4. SIZE.—The 40 feet straight measurement, to the mesial cleft of the tail, was increased only 1 foot by following the curves on the side, only half a foot when taken over the belly To the most posterior part of the tail-fin gave 9 inches more than to the median cleft.[1]

[1] The common statement that Megaptera when mature may reach a length of nearly 60 feet, appears to rest on the authority of Captain Holböll. Fabricius had put it at 50 to 54 feet, but even that would appear to be an unusual size. Mr A. H. Cocks (*The Zoologist*, 1884, 1885, 1886, and 1887) gives much interesting information in regard to finners, obtained during his visits to the

5. PECTORAL FIN.—The great length of the pectoral fin, or paddle, is the most striking character of Megaptera among all the whalebone whales. The following table shows the length of the paddle in proportion to the length of the entire carcase in those I have had the opportunity of measuring :—

	Length of Whale.		Length of Pectoral Fin.	
	ft.	in.	ft.	in.
Balænoptera musculus, Wick, 1869, . . .	65	6	8	8
Balænoptera musculus, Peterhead, 1871, . . .	64	0	7	8
Balænoptera musculus, Stornoway, 1871, . . .	60	6	7	1½ [1]
Balænoptera musculus, Nairn, 1884, ...	50	0	5	11
Balænoptera borealis, Orkney, 1884, . . .	35	0	4	7
Balænoptera rostrata, Aberdeen, 1870, . . .	14	6	2	2
Balænoptera rostrata, Bervie, 1877, ...	16	0	2	3
Balæna mysticetus, Davis Straits, 1873, . . .	48	0	8	6
Balæna mysticetus, Davis Straits, 1874, . . .	35	0	5	6
Megaptera longimana, Dundee, 1884, . . .	40	0	12	0

These measurements are from the head of the humerus to the tip of the paddle. That is little less than the measurement along the inferior (radial) border when the fin is still attached to the body. The measurement along the ulnar border is con-

Fin-Whale Fisheries, where large numbers of the various finners are killed. The common statements in regard to the lengths attained among the other finners are borne out, but not so in regard to Megaptera. Plenty of instances are mentioned of the Blue Whale (*B. Sibbaldii*) reaching from 70 to 80 feet, or more, giving averages of 75 and 79 English feet ; of the Razorback (*B. musculus*) from 60 to 70 feet, with averages of over 64 feet ; and of the Black Whale (Rudolphi's rorqual, *B. borealis*) from 40 to 45 feet, some nearly 50 feet. Of the Hump-back (*Megaptera longimana*) the largest averages of length were Captain Horn's, being, on a take of 6 males, 41½ English feet (the longest 53 feet), and of 2 females, 46½ feet (the longest 48 feet). Mr Cocks remarks—"The average for all the males whose length is given above is under 35½ English feet, while that of the females is just over 40½ English feet. The number of Humpbacks taken that year (1886) is given at 94 ; of the Blue Whale, 152 ; of the Razorback, 646; of Rudolphi's rorqual, 62 ; total 954, by 39 whalers." Mr Cocks says of the fishery of 1885— "Captain Berg told me that he had this season captured the biggest Humpback he had hitherto seen. It was a female, and measured 50 Norwegian feet (52 feet English) in a straight line (measured as Dr Guldberg had directed)." While the state of some parts of the skeleton will sufficiently show that my Megaptera was not full-grown, it would appear, from the lengths given by Mr Cocks, that a 40-feet male Megaptera is not so far from being adult as the nearly 60 feet statement might have led us to infer.

[1] In this *B. musculus* the length of the paddle would have been a little more but for a mal-development near the point.

siderably less. In the 50-feet-long *B. musculus* the length was 4 feet 2 inches along the ulnar border, 6 feet along the radial border, and after removal the measurement from the head of the humerus was the 5 feet 11 inches given in the table. In this Megaptera the measurements were :—inferior border, 12 feet ; superior border, 10 feet 3 inches ; along the middle, straight, 11 feet 8 inches ; from the head of the humerus, after removal of the fin, 12 feet. The measurement at the shorter border would give the pectoral fin of Megaptera a proportion of more than a fourth of the total length of the carcase ; that along the inferior border as rather nearer a third than a fourth. In the other great finners the proportion may be put at about an eighth, taken on the lower border.

The paddle in Megaptera is also of greater breadth than in other finners, though not than in Mysticetus.[1] In the 64-feet-long *B. musculus*, the greatest breadth was 19 inches, in the 50-feet-long one, 16 inches. In this Megaptera it is 32½ inches. The breadth is, however, not greater in proportion to the length in Megaptera than in the full-grown *B. musculus*, but rather less.

Another external character of the paddle of Megaptera is the very undulating anterior border, showing two greater and seven lesser nodes (see fig. 1), the causes of which are made clear by the dissection. A few lesser undulations are seen on the ulnar border towards the tip.

6. DORSAL FIN.—The form is shown in fig. 2. There is what may be called the fin proper and the basement, a low elevation from which the fin proper rises abruptly behind and gradually in front. The basement is marked off only by a gradual elevation from the general contour of the back. It extends from about 2 feet behind the tip of the fin proper to about 4 feet in front of it. Height of fin proper 7 inches, of the entire elevation 11 inches. Thickness at the middle of the fin proper, 1¾ inches; at base of fin proper, 3 inches ; of basement at its lower part, 12 inches; at 2 feet in front of fin proper, and at mid-height of basement there, 4 inches. In Rudolphi's

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[1] Mr Robert Gray informs me that his father, Captain David Gray, this summer caught the largest Right Whale (*Balæna mysticetus*) he has ever taken, a female 57 feet long ; length of the pectoral fin, measured along the middle of the outstretched fin, on the inner surface, 8 feet 2½ inches, greatest breadth 5 feet 1 inch.

diagram [1] the dorsal fin is not very like this one, stands up more, and the point and both margins are different. In the small figure given by Eschricht (p. 152, fig. 48), the notch is much less marked than in this one. As seen in my figure, the anterior slope is a little concave on the basement, and becomes convex on the fin proper. No exact spot could be fixed on here for the commencement of the fin proper as distinguished from the basement, but the level of the notch behind determines that to the eye. The point is some way behind the top, with a fall of about 1 inch. The posterior border below the point is convex down to the bottom of the notch. This, with the gentle concavity of the posterior slope of the basement, renders the notch pretty sharp, more so than in the higher and more recurved fin of *B. musculus*.[2]

As to situation, the distance from the cleft of the tail to the notch of the dorsal fin was 12 feet 4 inches of the 40 feet. In my 64-feet-long *B. musculus* the distance was 15 feet 8 inches (height of fin 15 inches, length at base 24 to 26 inches). This would place the dorsal fin further forwards in Megaptera than in *B. musculus*.

7. TAIL-FIN.—The form of the tail-fin is shown in fig. 3. Its greatest antero-posterior breadth was 3 feet, only $3\frac{1}{2}$ inches more than the breadth of the pectoral fin ; its total width less than the length of the pectoral fin by 8 inches. The statement of the depth of the median cleft, commonly said to be deep, will depend on where the measurement is taken. From between the neighbouring convexities, about 7 inches out, the depth is $3\frac{1}{2}$ inches; from between the first prominent serrations, about

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[1] *Abhand. könig. Acad. der Wissenschaften*, Berlin, 1829, Taf. v. fig. 1.

[2] I have noted these points particularly on account of the question of the origin of the name "Humpback" for this species. "Les mégaptères ont une bosse sur le dos à la place d'une nageoire"—"une véritable bosse dépendante de la peau," says the eminent cetologist P. J. van Beneden. There was nothing in the appearance of the back of this Megaptera to suggest to us the appropriateness of the name Humpback. That, however, will depend partly on the idea one associates with the word humpbacked. The name may have arisen rather from the rounded back Megaptera shows above water, as long ago suggested and figured by Eschricht (*Untersuchungen über die Nordischen Wallthiere*, p. 152, fig. 48) :—"Der Name *Humpback* scheint übrigens nicht nur von der Rücken-flosse, sondern eben so wohl von dieser Krümmung des Rückens beim Unter-tauchen." The term, though rather misleading as to the true form, is a convenient one to the whale-fishers.

16 inches out, the depth is 5 inches; from the most projecting part of the posterior border, more than half-way out, it is 9 inches; and from between the recurved tips the depth is 17 inches. The cleft proper is indicated in the first of these measurements, but some may have taken it at the third.

From tip to tip, straight, the tail-fin is 10 feet 6 inches; between the extreme edges in front of the recurved tips, 11 feet 4 inches.[1] The anterior border, after the neck, is convex throughout and very much bent back and also inwards, towards the tip. The falling in is 5 inches, so that the broadest part of the fin is in front of the tip. This great bending back extends on about 18 inches of the anterior border and 9 inches of the posterior border. The latter undulates; the broadest and most projecting convexity is external to the middle of each half; the concavity between that and the convex boundary of the median cleft is shallow; the concavity next the recurved tip is a deep bay, about 9 inches deep externally and 2 feet in width. The inward direction towards the blunt tip is mainly on the anterior border, but even the posterior border is here directed a little inwards. After the smooth convexity bounding the median cleft, the whole posterior border, out to the tip, is serrated; about twenty serrations may be counted (on each half of the fin), some large, some small, some sharp, some rounded. The antero-posterior breadths are, in inches, near the median ridge, 36; at junction of inner and second fourths, the same; midway out, $32\frac{1}{2}$; at junction of outer two-fourths, 24; at nine inches from the tip 7 inches transversely.

8. SURFACE OF THE ABDOMEN.—The *umbilical fissure*, or groove, 14 inches in length, begins immediately behind the plaitings of the skin. For 8 inches it is a well-marked elliptical fossa, deepest at the anterior end and feels hard at the middle.

The *preputial opening* is 3 feet behind the fore-end of the umbilical fissure. The epidermis is whitish here and for 4 or 5 inches back. From the preputial opening to the anus there is a groove in which the skin is soft. At the prepuce, at the white part, the groove is at first 4 inches broad and deep, over

[1] Straight from extreme to extreme is the usual way of measuring the tail-fin, but a truer method would be to measure straight from the extreme to the middle of the median ridge, giving the width of each half. Here that is 6 feet 3 inches, giving $12\frac{1}{4}$ feet as the axis of the entire tail-fin.

the cavity for the penis; it then narrows backwards to the mammillary pouch, and is narrow from that to the anus.

Mammillary Pouch.—This interesting part in this *male* Megaptera is situated 1½ feet behind the preputial opening and 2 feet in front of the anus.[1] The following is the arrangement (see fig. 4, natural size):—The opening of the marsupium, elliptical in form, is from 1½ to 2 inches in length, more sharply marked behind, grooved for ½ inch at the fore-end; breadth ¾ inch; the margins soft from the looseness of the subcutaneous tissue. The black colour continues

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[1] Referring to Pallas having first noticed the presence of mammillæ in the male cetacean, in the Beluga, Eschricht mentions particularly that their presence in male whales, fœtal and adult, has been well known to him. There is no reason why the milk glands should not be present in male whales as well as in male land mammals ; they cannot be more functionless in the former than they are in the latter, or than they are in man. The point of interest is how these significant rudiments are variously disposed. Eschricht found them present in all male cetacean fœtuses—"an der Mittellinie des Bauches ein Paar kleine schlitzenförmige Öffnungen," and that in the male porpoise (*phocœna*) " sie nach aussen hie zur einer einfachen Öffnung verschmolzen sind" (*loc. cit.*, 1849, p. 83). Professor Flower (*Proc. Zool. Soc.*, 1865, p. 701) found the arrangement in an adult male *B. musculus* to be that of two fissures, about 10 inches long, 1½ inch deep, and 3 inches apart, slightly converging posteriorly, each containing a nipple. The two-fissure arrangement, one on each side, more resembles that of the female. John Hunter described the position and structure of the mammary glands and nipples in the female cetacean (*Phil. Trans.*, 1787), and figured the nipples in their fissure in a 17-feet-long *B. rostrata* (Table xxi.). He describes the nipple as lodged in a sulcus on each side of the opening of the vagina, surrounded by loose texture, and, external to this, another small fissure, "which I imagine is likewise intended to give greater facility to the movements of all these parts." As these parts in my 14½-feet-long *B. rostrata* (1870) are preserved, I may here mention that they differ from Hunter's figure in the accessory fissure, instead of rather shorter, being much longer than the mammillary fissure. Length of accessory fissure 5½ inches on the left side, on right side 4¼; length of the mammillary fissure, 2 inches on both sides. The right accessory fissure passes as far back as the mammillary fissure, the left ¾ inch farther back. Breadth of skin between the two fissures 1 inch, being about the same as that between the vulva and the mammillary fissure. The nipple lies behind the middle of the fissure, concealed in it, ¼ inch or more from the surface, is flattened and now about ¼ inch in height, and is surrounded by a deeper and softer part of the fissure. An aperture in the summit admits a crowquill, and a little way along the duct, in the nipple, two or more apertures are seen. The accessory fissure is deeper than the mammillary fissure. In my 16-feet-long *B. rostrata* (1877) the accessory fissure has not been preserved. The mammillary fissures are each 2 inches in length. The middle ½ of the fissure forms a special fossa round the base of the nipple, 1 inch deep from the surface, thrice as deep as the anterior and posterior parts of the fissure. The flattened nipple is ¼ inch in height.

to a little within the edge of the opening, where the walls of the pouch and all the parts within it become white or cream-coloured. Plugging the mouth of the pouch is a large soft projection like the pulp of the thumb, as if a distended septum, but the lining membrane of the pouch dips in half an inch before and behind it, the depth of the pouch being about $1\frac{1}{4}$ inch at other parts. The nipple is brought into view by pushing aside the septal plug or the outer wall of the pouch, as seen in the figure. The nipple, flattened sideways, projects like a thick tongue, $\frac{3}{4}$ inch in height, $\frac{1}{2}$ inch in breadth. On the outer side of the nipple, a little way from the summit, is a large aperture, admitting a goose-quill, shortly within which two apertures are seen, as if the main duct there divided. Into one of these a middle-sized probe passed readily for $1\frac{1}{4}$ inches. The whitish epithelium on· the median plug and nipples was about $\frac{1}{20}$ inch thick, and when this was removed, the cutis vera on the summit of the plug and nipples presented tufts instead of the fine filiform processes which their other parts showed. In one of the photographs, taken the day after the whale was beached, the median plug can be recognised bulging moderately in the mouth of the pouch.

9. THE PLAITINGS OF THE SKIN.—These are much broader and consequently fewer than in other finners. The breadth is about $4\frac{1}{2}$, or maybe 5, inches. The furrows, after a few inches, have gained a depth of 1 inch and reach a depth of 2 inches, some $2\frac{1}{2}$, and are dark to the bottom. The number of plaits is about twenty-four. They extend from below the lower jaw to the front of the belly, ending there on a line drawn from 2 feet behind the axilla to the umbilicus. Two of the furrows, the 2nd and 7th below the axilla, are not continued forwards; the same of the 11th, but it is longer. The median furrow is not continued so far back as those next it. There is a short (13 inches) azygos furrow to the right side of the umbilicus, which if continued forwards would have split the median plait. The line seen in fig. 5 above the shoulder is not one of these furrows, but only a fold of the skin. The system of furrows begins below the side of the mandible, below the labial groove, by two furrows, closed at each end, as shown in fig. 5. The furrows of the throat run forwards close to the mandible, within 2 inches of it,

towards the symphysis, within about 5 inches at the sides. When the carcase lies on the belly, plaitings are thus visible below the mandible. Where the skin turns in from this to below the throat the plaitings present white patches, and this part is seen to form a projection, like a second chin, in figure 1 when the carcase lies on the back. A little behind this two of the furrows terminate, two of the plaitings having bifurcated backwards at the fore part of the throat. All of the long furrows are not continued throughout the length of the plaited area. Thus, the second and third furrows below the axilla are confluent backwards at about 2 feet in front of the axilla; a furrow at about half-way between the axilla and the mesial line ends opposite the axilla; and the fourth furrow below that one, mesial or nearly so, stops about 2 feet farther back, and is the lower limb of a furrow which has bifurcated backwards about 5 feet in front. The furrows seen in figs. 1 and 5 are exactly as in the photographs. I could not ascertain whether the furrowing is quite symmetrical.

10. DERMAL TUBERCLES ON THE HEAD (see fig. 5).—These large dermal tubercles rise to a height of 1 inch, one or two of the posterior of the median row to $1\frac{1}{2}$ inch. They are elongated antero-posteriorly. All are soft when pierced. On the upper jaw the median row has seven tubercles, at distances varying from 6 to 12 inches, which are connected by a low median ridge. The lateral row has eight on the right side, eleven on the left, but arranged in pairs except the foremost and hindmost, and are therefore at longer intervals than in the median row. On the mandible there are, along the side, six, the two hindmost low down, the other four arranged in a row high up; and close to the symphysis there are six on each side, forming an irregular cluster, placed mostly below the middle of the symphysis, the tubercles projecting like the end of a hen's egg, some twice that size. There are thus twenty-six great tubercles on the upper jaw, twenty-four on the lower.

11. HAIRS.—Most of the hairs seen on the lower lip had disappeared before I could attend to them. The eight which I took out vary from $\frac{3}{4}$ to 1 inch in length, are white and pretty stiff. They were readily seen by standing sideways to the tubercles. They projected $\frac{1}{4}$ to $\frac{1}{3}$ inch and came out easily

between the finger and thumb. It had been noticed before that some of them projected ¾ to 1 inch, but whether this was natural or owing to the hair coming out I cannot say. If the piece of black epidermic sheath adhering is to be taken as marking where the follicle began, one of the eight I have preserved must have projected for ½ inch. Our inability to find hairs on the upper jaw was not surprising, as the brushing and usage this part had received had already removed the epidermis. Those I took out grew from the tubercles at the symphysis, but one was found two feet back from the symphysis, on the second lateral tubercle, projecting about ¼ inch. It is an interesting question in what relation the tubercles and the hairs stand to each other.

12. ADAPTATIONS OF THE JAWS.—The projection of the lip of the mandible beyond the upper jaw is, at the front 13 inches; at the side, before the labial groove begins, 13½. The thickness of the soft tissue (lip or gum) forming the upper edge of the mandible was, at 1 foot from the symphysis, 2 inches; at the side, where the labial groove begins, about 6 inches.

Labial Groove (see fig. 5).—At 3½ feet from the symphysis, being about one-third of the distance along the side of the mouth, the lip bifurcates to form a deep broad groove, the inner boundary of which is the continuation back of the jaw, the outer border cutaneous. This groove deepens and broadens backwards to a breadth of 15 inches as a deep grove, and, becoming gradually shallower and broader (reaching a breadth of 30 inches), it is lost on the surface on a line drawn from the angle of the mouth downwards and forwards. The furrow seen below the shoulder in fig. 5, as if continued from it, is not a continuation of it. The whalebone range descends within the mandible, and the water escaping from between the plates will be conducted backwards along this labial groove. I am not able to say whether this great spill-water groove is in any way peculiar to Megaptera.

13. CUT-WATER.—At the point of the mandible, which is blunt (transversely 8 inches, vertically 7 inches), a median ridge goes down to a median projection, placed like a prow or cut-water. The height of this cut-water is 14 inches; breadth, 2 inches; amount of projection, 4 inches, the lower third

sloping backwards. The vertical measurement of the symphysis and cut-water together is 21 inches.

14. THE WHALEBONE.—The largest plates are 20 inches in length. At the front for $3\frac{1}{2}$ inches there are no plates, only about $\frac{1}{8}$-inch-thick bundles at the gum, breaking up into hairs, but the two sides quite meet at the mesial line. The first plate has, on the outside, 2 inches of plate proper and 2 of fringe. Entire length of the range, 8 feet 2 inches at the top, at the fringe 9 feet. The following is the length of the plates, in inches, at different parts:—At 2 feet from the front, $11\frac{1}{2}$; at 4 feet, 7 ; at 6 feet, 20 ; at 7 feet, the same ; at 8 feet, 10 inches. The range ends behind in short bundles with fringe. The length of the hairy fringe below, along the range, is, at 6 inches from the front, about 2 inches; at midway back, about 3 ; at the longest plates, 5; behind this the fringe shortens to 4 inches. The backward obliquity of the fringe is greater than that of the plates. The most anterior plates are nearly vertical; when the middle is reached the slope backwards is equal to the breadth of nine of the plates as they appear externally. At 20 inches from the back the plates are nearly vertical; then they become vertical, and at the very back seem to slope a little forwards. The greatest breadth of the longest plates is 5 inches. Breadth of roof of mouth between the whalebone ranges is, at 1 foot from the front of the whalebone, $6\frac{1}{2}$ inches; at 2 feet back, 8 inches ; at $3\frac{1}{2}$ feet back, 9 inches.

In colour, the whalebone on the outside was black, except along the front 12 inches where it was partly white, mottled, but differing in this respect on the right and left sides. On the left jaw here, at 6 inches from the mesial line, fifteen plates are quite white on their anterior half but black on the palatal half. Some near these, again, have the anterior edge black and the rest of their surfaces white. Viewed from the palatal aspect, the whole matting of hairs was whitish. The words in my note-book are " white, dirty-white, or yellow-white." Now, in 1887, after three years' exposure, though washed clean, that description could not apply. The colour of the hairy matting now is dirty-brown mixed with brown-black. The hairs are fully 4 inches in length, some 6 inches. The hairs of the fringe are thick and stiff, like bristles, compared with those of my

50-feet-long *B. musculus*, but the much finer hairs of the matting on the palatal aspect do not differ in thickness in these two whales.

15. BLOW-HOLES.—The length of the blow-holes is 11 inches; distance between hinder ends, 9 inches; between fore ends, 3 inches. They are a little convex towards each other. The median fissure has a depth of 1 inch at the middle. There is an elevation of the head here, rising about 3 inches, on the hinder slope of which the blow-holes are situated.

16. EYE, AND EAR-HOLE.—The *eye* is placed very close behind and above the angle of the mouth. The *ear-hole* is 17 inches behind the posterior canthus of the eyelids, and 2 to 3 inches below the level of the eye (see fig. 5). The epidermis being off, I could not ascertain whether there was any change of colour here.[1] The tissue immediately around the aperture is softer, so that a shallow depression can be made by the end of the finger. This will facilitate collapse of the meatus. The aperture admits a rather small-sized uncut goose-quill. In form it is ovoid antero-posteriorly, the anterior end sharp-edged, the posterior and narrower end grooved, the groove prolonged for about the same length as the foramen. This form of the aperture of this mammalian vestige may be an adaptation to forward swimming. Water in the meatus will be less disturbed. The quill goes straight into the meatus, at right angles to the axis of the body and head, firmly grasped, for 1 inch in the right, for 2 inches in the left.

17. COLOUR.—As it lay on the back, the day after it was beached, exposed by the retiring tide, the whole carcase appeared black, except the under surface of the tail-fin and of the breast-fin, whose snow-white appearance formed a striking contrast. The photographs taken on the same day show some patches of white on the throat and chest, notably on the plaitings below the chin, as they turn in below the mandible, and a few less abrupt streaks and smaller spots here and there along the chest. I had the opportunity of examining the white marks on the abdominal wall more carefully. As if bounding the perinæum, there was on each side, 5 or 6 inches out from the

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[1] In my quite fresh 14½-feet-long *B. rostrata*, there was a white line leading backwards from the ear-hole for 9 inches.

mesial line, a white streak, like a chalk line on a blackboard. It began 2 to 3 inches in front of the mammillary pouch, and was seen as far as the epidermis was present, which was for 12 inches. The white went through and through the epidermis, and a corresponding groove was present in the cutis vera, traceable as far back as 10 inches behind the anus on the left side, on the right side only for 12 inches behind the mammillary pouch. The papillæ of the cutis were shorter and finer on the groove. Besides these perineal lines and the white at the prepuce, there were, near the mammillary pouch and forward to the umbilical region, white spots like hailstones, and towards the umbilical fissure a few white streaks. These streaks were, on the left side, some 6 inches from the mesial line, and linear, and on the right side a row of spots corresponded to one of the streaks of the left side. These white streaks went through and through the epidermis, and corresponding grooves were present in the cutis vera.[1]

[1] *Variations in the Colour of Megaptera.*—The colour of the *outer surface of the pectoral fin* in this Megaptera was stated to me, by observers who had good views of the whale as it sported in the Tay, to be black. But where it lay on its belly at Dundee that surface was variously stated to me to be white, to be black, and to have black patches. When I went to dissect it at Dundee the epidermis was off. Statements of the colour of parts of a whale when not fresh, and not made by an experienced observer, are not reliable. When the epidermis is off, the cutis vera is at first white or cream-coloured, like the skin of a well-washed white pig; then under exposure for some time to the air it becomes bluish, and on being scraped, the cream colour is restored. The acquired bluish colour appears to be on the fine hair-like papillæ of the cutis vera. In regard to the question of the colour of the *outer* surface of the paddle of *Megaptera longimana*, Eschricht says (p. 147)—"Die Brustflossen aber sind an beiden Flächen rein weiss." From the account given by Mr A. H. Cocks (*loc. cit.*) of a number of Humpbacks he examined on shore, it would appear that there is considerable variation in the colour of this part. He notes, 1884—(1) Male, 40 feet, paddles black on the outer side, white on inner side, the black extending to round the borders, " with an occasional blotch of black, and two or three black rings " also on the inner side ; length of paddle to head of humerus 11 feet 4 inches, greatest breadth 3 feet 2 inches. " The throat with the furrows and nearly the whole of the under side was white." (2) Male, 44 feet, outer surface of paddles black on the proximal quarter only. Length of paddles 15 feet (measured to skin of axilla about 13 feet 9 inches), greatest breadth 3 feet 7 inches. (3) Male, 30 feet, paddles " only black on the upper side a little way down from proximal end." In 1886—(4) Male, 35 feet, outer side of paddles " black for only a very short distance at the proximal end." (5) 41–42 feet, outer side of paddle black only on proximal quarter, " the black extending down the anterior edge, with a few small irregular black marks lower down." (6) Male, 42 feet, " very little black on the outside of the flippers, including a narrow rim along the hinder edge."

18. SKIN AND BLUBBER.—The epidermis on the part of the abdomen, which I had the opportunity of examining carefully, was from ⅛ to ¼ inch thick. The cutis vera, when denuded of epidermis, had the cream colour already noted. The blubber at the fore part of the carcase was 4 inches thick, at the back part scarcely 3 inches, gradually diminishing from the middle back to the anal region where it was only 2½ inches thick.

19. PARASITES.—When beached at Stonehaven, parasites, seemingly of the usual kind (Diadema) found on Megaptera, were seen, but they were taken away by visitors. I noticed some on the distal part of the pectoral fin (inner surface) and some on the abdominal wall. The marks of the latter remain on the part of the wall which was preserved. One is seen on each side of the mammillary pouch (1½ to 2 inches from it)— large oval excavations, 2½ inches by 1½ inch; depth at the middle, one ¼ inch, the other nearly ½ inch; the sloping edge of the epidermis is white at some parts; the cutis vera is smoothly excavated. A third is seen close to one of these; and about 1 foot forwards, on each side of the prepuce, 2 to 3 inches from the mesial line, three such excavations are present.

Length of flipper 12 feet 11 inches. This Megaptera was "entirely black on the belly, but nearly the whole of the thorax (i.e., chest and throat) was white, the chin being black, with a few white flecks." So experienced an observer as Mr Cocks was not likely to be misled by skin denuded of epidermis. The two last-mentioned whales had been brought into the factory only during the night before. It would seem, therefore, that, while the whole outer surface of the paddle may be black, the black is usually confined to the proximal fourth or less. This will be the part most visible above water, which may account for the impression of those whose observation was confined to the living animal that the outer surface of the paddle is black. The white colour of the under surface of the throat and chest in Nos. (1) and (6) of Mr Cocks' specimens, above noted, is a remarkable variation. My impression is that the mesial part on the under surface of the tail-fin, in my Megaptera, did not partake of the white colour shown by the rest of that surface.

Captain David Gray, of Peterhead, who has had a very large experience in the Greenland whale fishing, informs me, in regard to irregular white patches, that wounds and scars, such as are caused by ice or rock scratches or fighting, heal white. Also that the natural white increases in extent and degree with age in Mysticetus.

20. EXPLANATION OF PLATES V. AND VI.

Fig. 1. View of the whale as it lay on the back at Stonehaven, drawn by Mr A. Gibb, from a photograph by Mr George W. Wilson, of Aberdeen, taken on the day after it was beached there. The plaitings of the skin on the throat, chest, and abdomen are exactly given. The throat is concave, the tongue having floated out of the mouth with the retiring tide. White patches are seen on the projecting skin where it turns in below the mandible, and a few less marked patches of white on the throat and chest. The inner surface of the pectoral fin, and under surface of the tail fin, are seen to be white. The pectoral fin lay abducted, and was much foreshortened in the photograph. I have drawn it directed more naturally backwards, and rotated outwards, giving a full view of its length and breadth, and showing accurately the nodes on its lower (radial) border, nine in number, the first and fourth nodes the most prominent. A rapid fall is seen on the contour from an angle some way behind the anus, presumably from the longer chevron bones backwards.

Fig. 2. The dorsal fin, reduced to $\frac{1}{36}$th. The two kinds of shading represent the distinction between the fin proper and its basement. The position of the highest part and of the point, and the form of the notch are exactly given.

Fig. 3. The tail fin; reduced to $\frac{1}{36}$th. The inward curve of the tips is seen.

Fig. 4. The mammillary pouch and the nipples; natural size. The sides of the pouch are hooked out so as to bring the nipples into view, on each side of the median septal plug. The aperture of the primary milk duct is seen some way down on the outer side of the nipple. The full size of the aperture is shown on the right nipple.

Fig. 5. From a photograph taken at Dundee by Mr F. G. Roger, of Broughty Ferry; reduced to about $\frac{1}{40}$, being the size of the photograph. On the upper jaw are seen the dermal tubercles, the median row single, the lateral row mostly in pairs. On the mandible the more posterior of the lateral tubercles on it are seen. The commencement of the plaitings of the skin is seen below the mandible. a, The cut-water; b, the position of the blow-holes, on the hinder slope of an eminence; p.f., commencement of the pectoral fin; e, the ear-hole, e.g.; the labial, or spill-water, groove. The narrow groove below the shoulder is not a continuation of it. The tongue is not seen, having fallen out.

(To be continued.)

ON THE MYOLOGY OF *ERETHIZON EPIXANTHUS.*

By Bertram C. A. Windle, M.A., M.D. Dubl., *Professor of Anatomy in the Queen's College, Birmingham.*

Good accounts of the anatomy of *E. dorsatus*,[1] which includes a description of the limb muscles and of the anatomy of *Dasyprocta cristata*,[2] with notes on rodent myology, have been written by Mivart and Murie, and are to be found in the *Proceedings of the Zoological Society.* The animal whose myology forms the subject of this communication, differing in some important respects from its near relative, the first-mentioned form, and from other rodents on account of its musculature, may not be without value. Only such points as present marked variations from the conditions described in the two papers above mentioned have been recorded in these notes. The specimen was a full-grown female, obtained immediately after death from Mr C. Jamrach.

Muscles of the Face, Head, and Neck.—From the inner angle of the orbit, and closely associated at its origin with the orbicularis palpebrarum, is a muscle which descends upon the nasal bones, and is inserted partly into the cartilage of the nasal aperture and partly into the skin. This represents the levator alæ nasi. The numerous branches of the infra-orbital nerve passing to the large hairs of the lip separate two sheets of muscle, both passing into the upper lip and acting as *elevators* of that part. Of these the superficial is connected with the lower part of the malar and the deep with the sides of the nasal bones and superior maxilla. Levator labii inferioris arises from the upper surface of the inferior maxilla close to the middle line, and just behind the incisors, and descends to be inserted into the lower lip. Depressor labii inferioris arises close to the middle line on the inferior surface of the inferior maxilla, turns round the margin

[1] " Notes on the Anatomy of *Erethizon dorsatus*," St George Mivart, *Proc. Zool. Soc.*, 1882, p. 271.

[2] " On the Anatomy of the Crested Agouti (*Dasyprocta cristata*)," St G. Mivart and J. Murie, *Proc. Zool. Soc.*, 1866, p. 383.

of the bone, and passing in front of buccinator, is also inserted into the lower lip.

Masseter is divided into three portions—

(1) Jugo-maxilien arises from the entire zygomatic arch, and by a strong tendon from the superior maxilla. This tendon is connected with the antero-superior angle of the muscle, and spreads out upon its superficial surface. It is inserted as in Agouti. (2) Mandibulaire, which is not well marked; and (3) Mandibulo-maxilien, which is well developed, are both placed as in Agouti.

Digastric, sterno- and cleido- mastoid, sterno-hyoid, and thyroid are as in Agouti. Omo-hyoid is present, and devoid of tendinous central portion. It is absent in Agouti.

Panniculus carnosus.—The dorsal portion is attached to the fascia over the supra-spinatus, the spine of the scapula, the deltoid ridge as far as its apex, and to the fascia of the arm below this for a short distance. The ventral part is attached to the inner surface of the deltoid ridge by a small flat tendon under the pectoralis minor. Emerging from under the pectoral muscles, it splits to enclose the mamma.

Muscles of Shoulder-Girdle and Upper Extremity.—Trapezius.—The nuchal portion of this muscle is very weak; the inferior part, on the other hand, is strong, and inserted into the spine of the scapula and on the fascia over the infra-spinatus.

Rhomboideus capitis and major form a single sheet of muscle, separated from rhomboideus minor.

Levator anguli scapulæ is fairly distinct from serratus magnus, and the first serration of this last is also to a certain extent separated from the main mass of the muscle, which is very strong.

Levator claviculæ passes from the atlas to the apex of the acromion and the fascia over the shoulder-joint.

Pectoralis major arises from the sternum from the 1st to the 6th rib, and is devoid of a clavicular portion. It is inserted into the distal portion of the deltoid ridge.

Pectoralis minor arises from the cartilages of the 4th to the 8th ribs inclusive, is quite separate from major, and is inserted into the capsule of the shoulder-joint and the proximal portion of the deltoid ridge. This muscle is not mentioned in the description of *E. dorsatus*, and is said to be wanting in Agouti.

Subclavius is a strong muscle in correlation with the extreme mobility of the clavicle.

Dorsi-epitrochlearis is large, and attached to the olecranon. Coraco-brachialis has an attachment to the middle of the humerus, and a second passing down to the internal condyle.

Brachialis anticus arises from nearly all the outer part of the deltoid ridge as high as the head of the humerus. It has no connection with the inner aspect of that bone, but is attached to its antero-external surfaces as low down as the external condyle.

Associated with the scapular muscles are two strong fibrous bands, arising from the junction of the upper and middle thirds of the axillary border of the scapula, and at first sight appearing to be independent ligaments. Of these the anterior is a part of the subscapularis, and is attached at its other extremity to the capsule of the shoulder-joint. The posterior is a portion of the teres minor, is larger and stronger than the anterior, and is attached to the apex of the acromion process on its outer and posterior aspect. From this band arise some of the fibres of the long head of the triceps, and under it passes the tendon of the teres minor.

Anconeus is quite continuous with triceps.

There is an extremely small supinator longus. This muscle is present in *E. dorsatus*; wanting in Agouti.

Pronator radii teres resembles the same muscle in *E. dorsatus*, save in not being attached so low as to the distal extremity of the radius. Its insertion is into a well-marked ridge.

Palmaris longus is inserted into the palmar fascia, and the ulnar angle of the cartilaginous plate on the radial side of the palm.

Flexor sublimis digitorum is a small muscle arising from the internal condyle. About the middle of the fore-arm its fibres become completely tendinous. To the lower portion of this tendon a second muscular belly is attached, which ends in four tendons, and not in a fascia, as in *E. dorsatus*. These tendons pass in the normal manner to the digits.

Flexor profundus digitorum consists of two parts, and is reinforced by flexor longus pollicis. These muscles are connected as follows:—(1) A portion arises from the internal con-

dyle, passes to the radial side of the fore-arm, and is there joined by the flexor longus pollicis arising from the distal portion of the flexor aspect of the radius. (2) The second part arises chiefly from the ulna, adjacent border of the radius, and interosseous membrane. This is reinforced by a slip from the internal condyle. The tendons of these two portions become closely connected under the annular ligament and pass to the digits.

There are four lumbricales.

Extensor communis digitorum sends tendons to the four inner digits. Extensor minimi digiti supplies minimus and annularis with tendons. Extensor indicis is extremely small, and its tendon does not reach the index, but is inserted into the fascia on the back of the carpus near this digit; it is closely associated with extensor ossis metacarpi pollicis, which is large, arises from almost the entire of the radial border of the ulna, and is inserted partly into the metacarpal of pollex, and partly into the cartilaginous palmar plate.

Supinator brevis possesses a sesamoid nodule.

The palmar cartilage, already mentioned, is shield-shaped, and overlies the palmar and radial aspects of the diminutive pollex; into it passes a portion of the extensor tendon, and under it and between it and the bones lie the short muscles of pollex, which are very small, and consist apparently of a blended abductor and opponens and a flexor brevis.

Minimus has an abductor, an opponens, and a flexor brevis, the last very small, the others fairly strong.

Palmaris brevis is very well marked.

Muscles of the Lower Extremity.—Gluteus maximus arises by lumbar aponeurosis from all the sacral vertebræ, and from the crest of the ilium as far forward as to its anterior superior spine, where for about a quarter of an inch the attachment is particularly well marked. The fibres descend in a broad sheet over the thigh, and separate into two parts. Of these, the posterior, which is comparatively narrow, is inserted by tendon into the junction of the lower and middle thirds of the femur. The anterior portion again divides into two parts, of which the posterior is attached to the fascia on the outer aspect of the thigh, and represents tensor vaginæ femoris. The anterior winds to the inner side of the knee, and is connected with the

fascia over that joint, but not specially to any bone. This appears to represent sartorius. None of these portions are in the least separated at their origin.

Posterior to gluteus maximus, and apparently belonging to the same stratum, is a muscle whose fibres, arising by lumbar aponeurosis from the spines of the upper caudal vertebræ, are closely connected with the gluteus maximus until its insertion, when they leave it to form a tendon which winds round the inner side of the leg, and is attached to the middle part of the anterior aspect of the tibia.

Gluteus medius is as in Agouti. I could not distinguish any separate minimus. There is a well-marked scansorius, and a distinct pyriformis.

The chief part of biceps arises by small distinct tendon from the outer part of the tuberosity of the ischium. The fibres diverge, and are inserted in three portions—(1) into the fascia on the outer side of the patella, (2) by a distinct tendon into the projection on the head of the fibula, (3) into the fascia of the leg as far as the heel, where it is closely connected with bicipitis accessorius, which is a very long slender muscle, arising by tendon from the transverse process of one of the upper caudal vertebræ, and inserted by fascia into the posterior part of the os calcis and tibia.

Adjutator caudæ is a broad muscle, arising from the transverse processes of the upper caudal vertebræ, and attached below by a small tendon to the outer side of the patella, part of its fibres passing into the fascia below.

Semimembranosus is a long slender muscle, arising beneath the last, and ending by a slender tendon, which is attached to the posterior part of the inner condyle of the femur.

Semitendinosus arises from the tuber ischii, and from the adjacent part of the ramus of the ischium, and is inserted into a ridge on the tibia, external to the internal lateral ligament, and by fascia above and below.

The adductor group of muscles corresponds fairly closely to *E. dorsatus.*

The flexor muscles of the toes are very complicated in the arrangement of their tendons. The perforating tendons are formed by flexores accessorius digitorum longus and hallucis.

The first of these is large and strong, and arises from the under part of the tuberosity, and from the external part of the body of the os calcis, sends a tendon to hallux, the remaining portion joining the tendon of the long flexor. The tendon thus formed unites with that of flexor hallucis.

As far as the different factors can be isolated, the toes are supplied as follows :—

Hallux by accessorius alone.

2nd toe by accessorius and flexor longus digitorum.

3rd toe by flexor digitorum and hallucis.

4th and 5th toes by flexor hallucis.

The perforated tendons are formed by four factors—

(1) Plantaris, whose tendon winds round the tendo-Achillis. The chief portion of this tendon passes to the base of the 5th metatarsal bone. From its inner side a muscular belly comes off, which ends in two tendons (a and b).

(2) Flexor brevis digitorum arises from the posterior part of the lower surface of the tuberosity of the os calcis, and ends in two tendons (c and d).

(3) Arises partly from the fascia of the foot, but chiefly from the lower end of the tibia, close by the tendon of flexor longus hallucis, and ends in one tendon (e).

(4) A muscular mass, arising partly from the flexor accessorius, and partly from the combined tendon of flexores digitorum and hallucis, and ending in three fleshy tongues (f, g, and h).

From these factors the perforated tendons are formed as follows :—

5th digit, $a + f$.

4th „ $b + c + g$.

3rd „ $d + h$.

2nd „ e.

Hallux is guarded on its inner side by a cartilaginous plate overlying its short muscles. This plate is ossified at its posterior and superior aspects.

This ossified portion articulates with the internal cuneiform, and with the metatarsal of the hallux. It is connected with the latter by a small muscle running inwards and backwards

from the former, and capable of moving it. This may represent the opponens, as there is no other to be found. Besides, this hallux has an abductor and a flexor brevis.

Minimus has a much-united abductor and opponens and a flexor brevis.

There are peronei, longus, brevis, and quintus.

Extensor communis digitorum sends tendons to the 2nd, 3rd, and 4th digits. Extensor brevis digitorum to the three central.

NOTES FROM THE PHYSIOLOGICAL LABORATORY OF THE UNIVERSITY OF EDINBURGH.

A Triple Stain for Spermatozoa.

THIN sections should be cut from the testis of the newt (*Triton cristatus*) at the spawning time, and treated with eosine and iodine green. If the preparation has been successfully made, the head of the spermatozoon will be stained bright green, the intermediate segment violet, and the tail a brilliant pink.

If iodine green in solution be added to an excess of solution of eosine, a violet colour will be observed at the junction of the two fluids. The violet colour of the intermediate segment is therefore due to its staining with both the eosine and the iodine green.

Bonn and Retzius have stated that there is no intermediate segment; Schweigger-Seidel, Merkel, Flemming, La Vallette, and others admit the existence of the intermediate segment, but state that it is developed from the protoplasm of the spermatoblast; others, on the other hand, state that the intermediate segment, like the head, is derived from the nucleus of the spermatoblast.

Thin sections, however, suggest that the intermediate segment of the spermatozoon is affected by both dyes, and may possibly be developed from both nucleus and protoplasm of the spermatoblast.

These specimens were prepared, under Dr Carlier's direction, by Mr A. J. S. Beveridge.

Termination of Nerves in Capillaries.

This figure shows the termination of a nerve in a capillary blood-vessel. The original, of which the drawing is an exact copy, was obtained from a fresh sciatic nerve of a frog teazed in salt solution.

Two ordinary medullary fibres are seen A.

To the capillary B, filled with blood-corpuscles, passes the nerve C. This is a *fine medullated fibre*. Many such fibres are seen in every sciatic nerve.

Ranvier (*Traité technique d'Histologie*, p. 855) and others state that both medullated and non-medullated fibres pass to blood-vessels. Klein (*Elements of Histology*, p. 123) and others maintain that these are non-medullated. Dr W. H. Gaskell (*Journal of Physiology*, vol. vii.) maintains that *all* vascular nerves begin as fine medullated fibres, but lose their medullary sheaths in passing through nervous ganglia *before* they reach their destination in the vessels. This preparation demonstrates the inaccuracy of the views of the latter observers. We may assert avoiding dangerous generalisations, that certain fine medul-

lated fibres found in the sciatic of the frog terminate directly in capillaries.

It was impossible to make out from the preparation fuller details
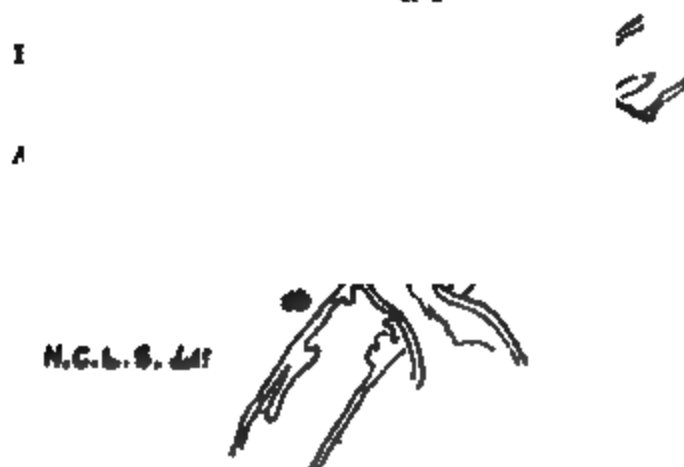
than are represented in the figure, although, being isolated in the salt solution, the blood-vessel could be moved about freely.

Egg and Serum Albumen Contrasted.

To differentiate between solutions of egg and serum albumen, the best chemical test is undoubtedly the addition of ether when egg albumen is coagulated, a true coagulum being formed, which is insoluble in water, whereas serum albumen is not coagulated.

In some works on physiological chemistry another test is given, *i.e.*, the addition of hydrochloric acid, when, it is stated, a coagulum is formed in both cases, that of egg albumen being insoluble in excess, whereas that of serum albumen is soluble.

So far as serum albumen is concerned, we found this to be correct ; but we found that the coagulum, in the case of egg albumen, is also soluble in excess, thereby rendering this test useless for differential purposes.

J. B. Haycraft.
E. W. Carlier.
Harold C. L. Scofield.

PROCEEDINGS OF THE

ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

An Ordinary Meeting of this Society was held at the Rooms of the Medical Society of London, Chandos Street, W., on Thursday, July 7, at 4 p.m.—Professor Humphry, F.R.S., in the chair. The following Rules were adopted:—

1. Those interested in the science of Anatomy shall be eligible for election as Members of the Anatomical Society of Great Britain and Ireland.
2. Candidates shall be proposed by three members, of whom one shall have personal knowledge of the Candidate.
3. The name and address of each Candidate, together with the names of his proposers, shall be announced at a meeting of the Society, and the ballot shall take place at the next meeting.
4. Not less than one full week before the meeting at which the ballot is to take place the Secretary shall send to every member of the Society the name and address of each Candidate, together with the names of his proposers.
5. Any member wishing to vote shall return to the Secretary, on or before the day of meeting, this notice, with the name of any Candidate to whom he objects crossed out.
6. One black ball in five shall exclude.
7. Each member of the Society shall pay an annual subscription of ten shillings and sixpence.
8. The subscription is payable in advance, and becomes due on the 1st of November of each year.
9. Any member whose subscription is not paid within twelve months after it has become due shall, if the Council see fit, be removed from the membership of the Society.
10. The Committee of Management shall fix the time and place of each meeting.
11. The Committee of Management shall determine the business of each meeting.
12. Each member shall have the privilege of introducing a visitor or visitors at any ordinary meeting of the Society. The names of visitors shall be entered into the attendance book, after which the visitors shall be permitted to join in the discussions of the Society.
13. The first meeting of the Society in the winter session shall be the Annual General Meeting.

14. One-fourth of the Members of the Council shall be replaced at each Annual Meeting by an equal number of members chosen from the Society at large.

15. The Council shall submit at each Annual Meeting a list of the members whom they recommend as officers during the ensuing year.

16. The Committee of Management shall arrange with the *Journal of Anatomy and Physiology* for the publication of the Proceedings of the Society, and of the papers read before the Society.

17. If at any time the Council shall be of opinion that the interests of the Society require the expulsion of a member, they shall submit the question to a special general meeting, at which, if two-thirds of the members of the Society vote for the expulsion of the member in question, his subscription for the current year shall be returned to him, and he shall thereupon cease to be a member of the Society. The voting at such special meetings shall be by ballot, and not less than twenty members shall form a quorum.

18. New Laws may be proposed by the Council at the Annual Meeting of the Society, or at a meeting specially summoned for the purpose, notice of the proposal being sent to each member of the Society with the summons to the meeting. At such meeting not less than twenty members form a quorum, and for the adoption of any rule a majority of two-thirds of the members present shall be required in its favour.

19. Any member may make suggestions to the Council regarding changes in the laws, by letter addressed to the Secretaries.

The SECRETARY then reported that the Council had elected the following gentlemen to the Committee of Management:—Alexander Macalister, F.R.S; John Curnow, M.D.; John Langton; G. D. Thane; J. Davies-Colley; G. B. Howes.

Professor MACALISTER then read a paper, entitled *A Note on some Common Errors in Descriptions of the Brachialis Anticus Muscle.*

The object of this communication was to show that the descriptions found in text-books of anatomy are wanting in accuracy, and a more precise method was advocated and exemplified in the case of the brachialus anticus.

A discussion followed, in which Professor Thane and Mr C. Stonham took part, the latter drawing attention to the peculiar striped appearance of the tendon of the muscle, and said it was of surgical importance in relation to ligature of the brachial artery.

Dr H. ST. JOHN BROOKS read a paper on the *Short Muscles of the Pollex and Hallux of the Anthropoid Apes, with special reference to the Opponens Hallucis.*[1]

[1] This paper is printed *in extenso* in the *Journal of Anatomy and Physiology,* 1887, vol. xxii. p. 78.

After describing the muscles of the pollex and hallux in the hands and feet of the specimens he had dissected (Chimpanzee, Orang, and Gibbon), the author compared his results with those obtained by Vrolik, von Bischoff, Duvernoy, Huxley, and others. He found that in the hand the Gibbon departed further from man, with regard to this particular group of muscles, than either of the two others. He found that this anthropoid differed from man—(1) in the proximal position of the adductor pollicis; (2) in the part-insertion of the adductor into the metacarpal bone of the thumb; (3) in the prolongation of two of the short muscles (adductor and flexor brevis) to the ungual phalanx; and (4) in the greater relative development and more palmar position of the true ulnar head of the flexor brevis. With regard to the hallucial muscles, many authors had described an opponens hallucis in anthropoids, but the author had only found *an opponens hallucis derived from the tibial head of the flexor brevis, and therefore homologous to the opponens pollicis* in the Orang. He believed that the opponens described in the other anthropoids consisted of some fibres of the adductor inserted into the metatarsal bone of the hallux. He had found such fibres in the three genera that he had an opportunity of examining.

In the discussion which followed, Professors HUMPHRY and MAC-ALISTER took part.

Mr J. BLAND SUTTON then read a paper, entitled *A Critical Study in Cranial Morphology.*[1]

In this paper an argument is raised to show that the embryological history of the skull, and a comparative study of its appendicular elements, as well as the morphology of the trigeminal, facial, and vagal nerves, support the view that the dura mater represents the primitive cranium, and that the term *extra-cranial* applies, morphologically, to all structures outside the dura mater; hence the Gasserian ganglion, geniculate ganglion, petrosal nerves, meningeal and internal carotid arteries, and the structures in the cavernous sinus are truly extra-cranial. The entanglement of these and other structures is due to the progressive development of the cerebrum.

Mr LOCKWOOD said he had often read Mr Sutton's paper on the temporal bone, and had followed it out upon fœtal skulls, and could confirm Mr Sutton's observations as regards the relation of the facial nerve and internal carotid artery. Although he had examined malar bones, he had never seen the three ossific centres which Mr Sutton mentioned, but only two. With regard to the lower jaw, whilst allowing that the investigation was exceedingly hard, he nevertheless could not find the various ossific centres mentioned by the author. However, he thought Mr Sutton's contentions were, on the whole, quite tenable.

Professor THANE agreed with Mr Lockwood's remarks as regards the malar bone and lower jaw, and wished to have the opportunity of

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[1] This paper is printed *in extenso* in *Journal of Anatomy and Physiology,* Oct. 1887, vol. xxii. p. 28.

examining the various specimens from which the conclusions were drawn.

Professor MACALISTER criticised Mr Sutton's description of the ossification of the lower jaw, and said he had long been accustomed to teach the relations of the petrosal nerves which Mr Sutton had described.

In reply, Mr SUTTON promised to bring the specimens which illustrated his paper to the next meeting of the Society.

Mr JAMES BERRY then read the following paper on the *Suspensory Ligaments of the Thyroid Gland :—*

The object of the brief communication which I have to make to the Society is to direct its attention to a pair of ligaments connected with the capsule of the thyroid gland, and which have hitherto, so far as I am aware, not received any notice.
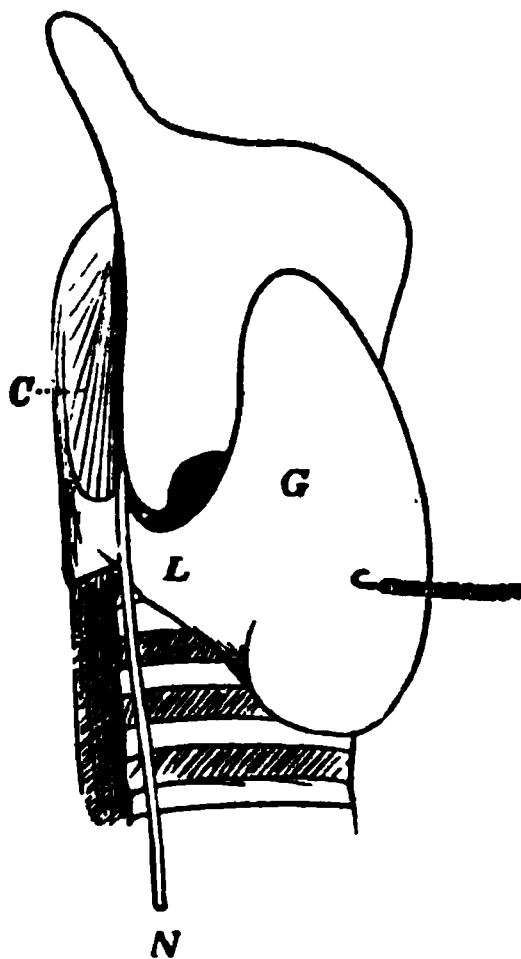
G, Thyroid gland drawn forwards ; *L,* suspensory ligament ; *C,* crico-arytenoideus posticus muscle ; *N,* right recurrent laryngeal nerve.

They are strong bands which pass from the inner and back part of each lobe of the gland upwards to the sides of the cricoid cartilage.

To prevent confusion, I may explain at once that they have nothing at all to do with the pyramid, that process of glandular or fibrous tissue so often found extending from the front of the gland upwards to the hyoid bone.

Blending below with the capsule of the thyroid gland they form on each side the upper end of a kind of sling, in which the organ is suspended, and by which it is firmly fixed to the cricoid cartilage.

They form, therefore, suspensory ligaments for the gland, and are the main bonds of union between it and the larynx, serving to keep these structures in intimate contact.

When the thyroid gland has undergone great enlargement, as in the common goitre, these ligaments are of much importance, forming strong cords supporting the tumour, which would otherwise tend, by its weight, to slip away from the larynx.

My reason for drawing attention to these ligaments is, that I believe that they are of some importance in connection with operations for the removal of goitre.

In these cases, as I have just said, they form strong bands, which have to be divided before the tumour can be detached from the larynx.

I have noticed, in operations of this kind, which I have seen performed by others upon the living, and in a large number of excisions of the gland which I have myself performed on the dead body, that most of the difficulty in the separation of the tumour has occurred in the region of these ligaments.

This difficulty I believe to be a very frequent source of that accident which so commonly occurs in the removal of goitre,—I mean division of the recurrent laryngeal nerve.

This nerve lies in immediate contact with the ligament in its posterior and outer surface; it lies, therefore, superficial to it during the operation, when the tumour has been partially separated and turned over towards the middle line.

I think that if the position of this ligament were a little better known, the separation might be effected with much less dissection by simply cutting through it close to the gland; there would then be much less danger of wounding the nerve or of opening the trachea—an accident which is known to have occurred on several occasions.

I ought also to mention that this ligament, like most others, has no very definite and abrupt margins, but is continuous with the thin layers of fasciæ on either side of it, one of which, on the inner side and on the same level, is attached to the whole of the anterior surface of the cricoid cartilage, while the other below it passes to the posterior surface of the trachea.

In the two specimens which I have brought for your inspection— one of which appears to be the seat of some goitrous enlargement— glass rods have been placed under these ligaments.

Professor HUMPHRY said that Mr Berry's specimen showed that there were two strong ligaments. ·

Professor CURNOW then drew attention to a specimen which he had brought, namely, the *Right Subclavian Artery passing in front of the Scalenus Anticus.*

This drawing is taken from a male subject, aged 28, dissected at King's College during the present summer session. The vein passed in front of the artery as usual. The artery is in its ordinary position on the first rib, but the scalenus anticus muscle and the tubercle for its insertion are placed much more posteriorly than normal. The cords of the brachial plexus are behind the scalenus anticus. The left subclavian artery and the left scalenus anticus were in their normal positions. Quain did not meet with this variation in 296 cases, but figured it from a preparation at St Bartholomew's Hospital.

Similar cases are reported by Manec, 1832 ; Lizars, 1834 ; Hird, 1837 ; Velpeau, 1839 ; Demeaux, 1841 ; Duval, 1853 ; Schwegel ; Bochdalek, junior, 1867.

Ab., innominate artery ; 1, scalenus anticus ; 2, thyroid body ; 3, trachea.

Its occurrence has been estimated as 1 in 150 cases, but it is certainly much less common than this.

Messrs RICKMAN GODLEE and CHARLES STONHAM showed an interesting series of anatomical specimens and casts of bronchi.

Dr J. COLLINS showed an abnormal Aortic Arch.

Mr LOCKWOOD showed a method, suggested to him by Mr Houghton, the glass manufacturer, of mounting frozen sections in large flat photograph glasses.

The PRESIDENT announced that the next meeting would be held late in November, at University College, Gower Street.

V.D.

36

2

W.D.

P.C.

29

34

T.E.

Gm.

C.T.

W.D.

35   T.E.

V

M.T.

32

28

31

G.L.

W.T.

X

Ao

Gm

C.V.

*a*ˣ

Fia 2.

b

v

tr

a²ob.

Fig. 5.

abd² ....

Fig. 3.

Fig. 2.

Fig. 1.

Fig 1 MEGAPTERA LONGIMANA.
(FROM A PHOTOGRAPH AT STONEHAVEN, near ABERDEEN, 1884)
LENGTH 40 FEET.

Fig. 2.

Fig. 3.

Mammillary Pouch and Nipples
of Male Megaptera
(NATURAL SIZE)

Fig. 2, 1/36

Fig. 3,
1/36

Fi.

Mammillary Pouch and Nipples
of Male Megaptera.
(NATURAL SIZE)

Fig. 4.

a^x

b

v

tr

$a^1 o b$
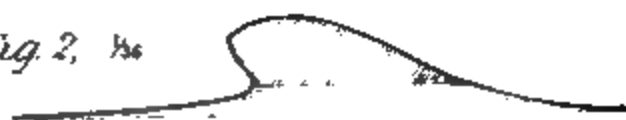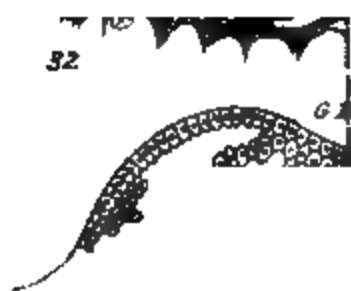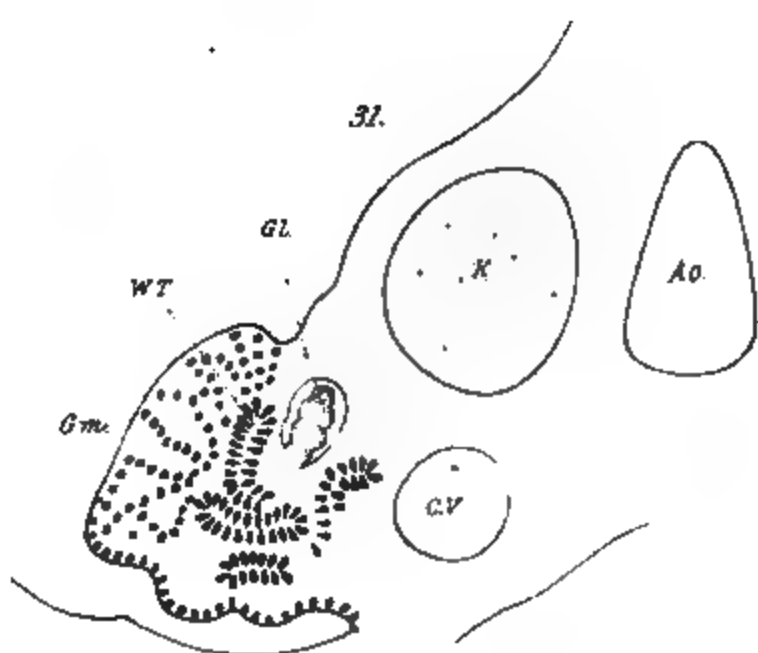
Fig 1   MEGAPTERA LONGI...

(FROM A PHOTOGRAPH, AT STONEHAVEN, near ABERDEEN, 1884.)

LENGTH 40 FEET

Fig. 1. MEGAPTERA LONGIMANA.

(FROM A PHOTOGRAPH, AT STONEHAVEN, near ABERDEEN, 1884.)

LENGTH 40 FEET

Fig 2. ⅙₆
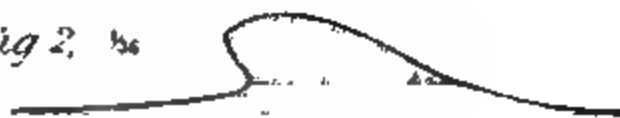
Fig 3.
⅙₆

Fi.

Mammillary Pouch and Nipples
of Male Megaptera
(NATURAL SIZE)

THE TONGUE AND GUSTATORY ORGANS OF *FIBER ZIBETHICUS*. By Frederick Tuckerman, M.D., *Amherst, Massachusetts*. (Plate VII.)

THE tongue of this rodent was prepared for histological examination in the following way. The fresh organ was placed for twelve days in a mixture of 5 parts Müller's fluid and 1 part alcohol. It was then, after being washed for thirty-six hours in running water, transferred to ordinary spirit, where the hardening was completed. Subsequently it was divided into segments, which were embedded in colloidin according to the usual method.

General Account of the Tongue.—The shape of the organ suggests a division into an anterior and a raised posterior part. The two divisions are of about equal length. The length of the tongue from the base to the apex is 45 mm.

The anterior division is free from the floor of the mouth for 13 mm. or a little more than one-half its length. It measures 9·7 mm. in breadth and 6·5 mm. in thickness. Where it joins the posterior division (about the middle of the tongue) the breadth is 8 mm. and the thickness 8·2 mm. The upper surface is slightly convex anteriorly and flattened posteriorly, and is covered with fine small densely packed papillæ, the apices of which are directed backwards. A very well defined median groove, 12 mm. long, passes directly through the tip of the tongue, and is continued on to its under surface for a distance of 1 mm. Near the line of union of the anterior and posterior divisions there is a slight trace of a mesial groove running forwards along the anterior part for 6·5 mm. The apex is rounded and somewhat broad, and measures nearly 4 mm. in thickness. Papillæ of the fungi-

form type are not very numerous, and are limited to the anterior dorsal surface of this division. The under surface is perfectly smooth, and unmarked by any median raphé or groove save the one mentioned above.

The posterior division is 9·5 mm. in breadth and 11 mm. in thickness. The surface, which is a dark rusty-brown colour, is convex, and in front of the circumvallate papilla is covered with fine thickly placed papillæ, the points of which are directed backwards. The anterior extremity is elliptical in form, and is raised 2·5 mm. above the upper surface of the anterior division. At its lateral and anterior limits are scattered a number of large coarse dark-coloured papillæ. In the median line of the tongue, about 5 mm. from the base, is situated a single papilla of the circumvallate type. It measures across the upper surface 1 mm. The trench in which it exists does not completely encircle it, as anteriorly, for a breadth of 0·75 mm., it is attached to the surrounding parts.

On each side of the tongue, 6·5 mm. below the summit of the raised posterior part, and hardly discernible to the naked eye, is situated a papilla foliata. These papillæ lie imbedded in the organ, the crests of their ridges barely rising above the level of the surface. Each papilla measures 3 mm. in length, and its anterior extremity is 29 mm. from the tip of the tongue.

The Circumvallate Papilla.—The upper surface of this papilla is rounded, with nearly symmetrically sloping sides, and at its widest part is about 1·15 mm. in diameter. The sides are 0·45 mm. in length, and at their lower part bend inwards and downwards. The width of the trench is quite uniform in its upper half, becoming gradually narrower as it curves inwards at the base of the papilla. The upper angle of the outer wall of the trench is 0·15 mm. below the summit of the papilla. Serous glands are present within the papilla, but are mainly limited to its base. Both serous and mucous glands (the former being by far the more numerous) are very abundant in this region of the tongue. The ducts of the serous glands open into the bottom of the trench. At its upper part the papilla bears many secondary papillæ, both large and small, the depressions between which are filled by the epithelium.

At the lower part of the papilla, midway between its sides, is

a large ganglion [1] (0·3 mm. in diameter), the upper surface of which reaches the level of the middle of the papilla. It is surrounded by a very well defined connective tissue capsule, portions of which enter the body of the ganglion and give it support. Above and at the sides of the ganglion nerve fibres radiate outward towards the sloping side containing the taste-bulbs. The nerves are non-medullated, but possess a distinct primitive sheath, and their oval-shaped nuclei are clearly seen. The nerve cells are numerous, fairly uniform in size, and quite evenly distributed throughout the ganglion. They vary somewhat in shape, but are usually either oval or spherical. They contain large rounded or oval-shaped nuclei with granular contents.

The taste-bulbs are only fairly numerous in the circumvallate papilla. They are arranged along the side in a zone of five or six tiers, the upper tier not reaching to the level of the middle of the trench. In a horizontal section I counted sixty bulbs, which, if we allow for six tiers, will give approximately 360 bulbs for the papilla.

Taste-bulbs are also normally present (I found them in every section) in the lower third of the outer wall of the trench. Here they appear regularly arranged in a belt of three or four tiers (see fig. 1). In a horizontal section I counted forty bulbs, which, allowing for four tiers, would give 160 bulbs occurring in this region. If we add these to the 360 of the papilla, we shall have a total of 520 for this gustatory area. In several sections I found single bulbs situated in the epithelium of the papillary wall in its upper half, but failed to find them on the free upper surface.

The bulbs vary considerably in size and shape (fig. 2 shows the structure of the bulbs magnified 200 diameters). The average length is about 0·07 mm., and the average breadth about 0·04 mm. In some the neck is short, while in others it is long and narrow. I failed to find a bulb with hair-like processes protruding through the pore. The nuclei of the peripheral cells stain deeply in hæmatoxylin. The outer layer of

[1] Poulton has already called attention to the presence of a large ganglion in the circumvallate papilla of *Perameles nasuta.—Quart. Jour. of Micr. Sci.*, vol. xxiii., 1883, p. 73.

epithelium, at the point of its perforation by the bulbs, stains a uniform yellow in picro-carmine. By teasing I was enabled to isolate a bulb (see fig. 9) with a nerve fibril entering its base, and apparently continuous with the central process of a cell.

The Papillæ Foliatæ.—The exposed surfaces of these papillæ are somewhat flattened. The folds are very irregular, causing great inequality in the breadth of the ridges and depth of the furrows. Of the latter there are six present, but two of them are very shallow, and in some sections are absent altogether. The three main furrows are of about equal depth (0·25 mm.), and are fairly uniform in width. Serous glands are very abundant around the papillæ, and their ducts generally open at the bottom of the furrows. The body of each ridge carries at its upper part from two to five secondary ridges, the depression between them being filled by the epithelium.

The taste-bulbs are arranged three or four tiers deep along the sides of the folds or ridges at their lower part, the uppermost tier not usually extending above the level of the middle of the furrow. Frequently the bulbs form a continuous gland around the bottom of the furrow. I estimated the number of bulbs in each papilla (as shown by horizontal and vertical sections) at 400 or 800 bulbs for the two papillæ. These, added to the 520 of the circumvallate papilla, would give 1320 as the approximate total number of taste-bulbs contained in the gustatory organs proper of this tongue. The bulbs of this region are on the average a little smaller than those found in the circumvallate papilla.

The Fungiform Papillæ.—These papillæ are small and are thinly scattered over the anterior dorsal surface of the tongue. They are flattened on the top, their free surface being covered by a quite thick homogeneous layer of stratified pavement epithelium. Their sides are vertical, or nearly so, and they are surrounded by cone-shaped papillæ, the points of which overtop them by 0·05 to 0·10 mm.

Taste-bulbs are far from common on the fungiform papillæ of mammals. In this little animal I met with a few isolated ones occurring in the epithelium at the upper part of the papilla. The best example is shown in fig. 6. Here the bulb is placed vertically, directly in the axis of the papilla, with its apex

against the inner surface of the homogeneous layer of stratified epithelium, and its base penetrating the mucosa. It measures about 0·06 mm. in length and 0·03 mm. in breadth. It is of a higher type of bulb than I have usually found on these papillæ.

The papillæ of mechanical function covering the anterior division of the tongue are conical in shape, and are quite uniform in size and general arrangement. They are densely packed, there being about 170 to the square millimètre of surface. Their apices are bent slightly inwards and backwards. They are smallest and nearest together upon the sides, and gradually increase in size till they reach the upper surface of the dorsum. Their average height and breadth is 0·3 mm. and 0·065 mm. respectively, and the distance between them about 0·02 mm. Each one rests upon a papillary projection of the mucosa. The epithelium covering them is dense and imbricated, and in their upper half is completely cornified. The intervals between the papillæ at their base are filled for a short distance with epithelium, which also is imbricated in arrangement.

The cone-shaped papillæ investing the upper surface and sides of the raised posterior division do not differ in character very materially from those of the anterior division. They are less thickly placed in this region, there being about eighty to the square millimètre of surface. The apices are more pointed, and are directed inwards and backwards. The papillæ are a little broader and lower, and the epithelium covering them is imbricated and completely cornified in their upper half. Occasionally a papilla divides in its upper third, terminating in two spiniform processes. At the anterior extremity of this division are scattered a number of coarse brownish-black-coloured papillæ. Structurally, and aside from their size and the pigment granules which they contain, these do not differ essentially from those just described.

On the posterior surface of the epiglottis I found, in nearly every section, bulb-like structures embedded in the stratified epithelium. The two forms most frequently met with are shown in figs. 7 and 8. The former, the more common, measures 0·055 mm. in length and 0·04 mm. in breadth. The latter, of which I find comparatively few examples, measures 0·065 mm. in length and 0·03 mm. in breadth. In a number

of sections the apices of the bulbs reach the free surface of the epithelium. In a few instances their basal ends penetrate the mucous membrane to a considerable depth. I did not succeed in tracing nerve fibrils directly into the bulbs in this region.

EXPLANATION OF PLATE VII.

Fig. 1. × 25. Vertical section through the circumvallate papilla. *S.P.*, secondary papillæ ; *t.*, the trench ; *r.*, the ridge which surrounds the trench ; *t.b.*, the taste-bulbs arranged in tiers ; *t.b'.*, taste-bulbs situated in the epithelium of the outer wall of the trench ; *t.b".*, isolated taste-bulb ; *gn.*, ganglion surrounded by its capsule ; *gl.*, serous gland ; *gl.d.*, the ducts of the serous glands, opening into the bottom of the trench ; *m.m.*, mucous membrane.

Fig. 2. × 200. Vertical section through the base of the circumvallate papilla, showing the bottom of the trench and the five lowest tiers of taste-bulbs. *t.*, the trench ; *t.b.*, taste-bulb, the reference mark indicating the basal end ; *t.b'.*, taste-bulbs situated in the epithelium of the outer wall of the trench ; *g.p.*, gustatory pore ; *s.e.*, stratified epithelium ; *o.l.*, outer layer of stratified epithelium ; *gl.d.*, duct of serous gland ; *m.m.*, mucous membrane.

Fig. 3. × 45. Transverse vertical section through one of the papillæ foliatæ. *fd.*, the folds of the papilla; *S.P.*, secondary papillæ ; *f.*, the furrows between the folds ; *t.b.*, the taste-bulbs embedded in the epithelium of the sides of the folds ; *gl.*, serous gland ; *gl.d.*, the ducts of the serous glands ; *m.m.*, mucous membrane.

Fig. 4. × 95. Horizontal section through the base of one of the papillæ foliatæ, showing the sides of two opposed folds, with their taste-bulbs. *f.*, furrow ; *t.b.*, taste-bulbs ; *m.m.*, mucous membrane.

Fig. 5. × 45. Transverse vertical section through the anterior part of the tongue, showing the cone-shaped papillæ. *P.P.*, papillary projections of the mucous membrane entering each papilla ; *s.e.*, stratified epithelium of ordinary structure between the papillæ ; *m.m.*, mucous membrane.

Fig. 6. × 200. Vertical section through a fungiform papilla from the anterior part of the tongue. *t.b.*, taste-bulb ; *P.P.*, papillary processes ; *s.e.*, stratified epithelium.

Fig. 7. × 200. Transverse vertical section through the upper part of the posterior surface of the epiglottis. *f.s.*, free surface of the stratified pavement epithelium ; *b*, bulb-like structure, lying partly in the epithelium and partly in the mucosa; *m.m.*, mucous membrane.

Fig. 8. × 200. Transverse vertical section through the middle of the posterior surface of the epiglottis. *f.s.*, free surface of the epithelium ; *d.l.*, deep layer of the epithelium ; *b.*, bulb with its neck and body embedded in the epithelium, and its rounded base resting in the mucosa ; *m.m.*, mucous membrane.

Fig. 9. × 240. Longitudinal section through a taste-bulb, showing direct continuity between the central process of one of its cells and a nerve fibril.

THE HISTOLOGY OF THE SKIN OF THE HORSE.

By FRED SMITH, M.R.C.V.S., *Professor Army Veterinary School, Aldershot.* (PLATE VIII.)

So far as I am aware, the minute anatomy of the skin of the horse has never before been described. On some points the information I have given is by no means so complete as I should have liked, but it is hoped that the article may help to fill a void in veterinary literature.

It need hardly be said that the skin of the horse, generally speaking, differs in no essential respect from that of man; there are, however, some individual peculiarities to which we must devote especial attention, whilst those points which are the same in both animals will receive but little notice. Skin will differ in quality in different horses. In the race-horse, for instance, we have a skin particularly thin and delicate, the hairs which grow on it are very short and fine, and even the long hairs of the mane and tail are scanty and short. As we pass through the different degrees of breeding until we arrive at the cart-horse; we observe that the skin gets much thicker, coarser in texture, the hairs very much more abundant, coarser, longer, and even growing in profusion in parts which on the thorough-bred horse are barely covered by hair. The production of an abundance of hair, particularly if curly, and a thick skin are signs of underbreeding.

It would appear almost superfluous to say that the horse changes his coat twice a year, viz., at spring and autumn; in the former case he loses a warm for a fine short coat, and in the latter he gets rid of his fine coat for a long and often shaggy one. This changing of the hair is a point of considerable interest, and one to which especial attention has been directed in our histological enquiry. Apart from its scientific usefulness, a knowledge of skin function as learned by the microscope has its practical bearing. Horse-owners know that at the season of moulting horses are not so fit as they should be, and one of the most common excuses made for horses looking poor in spring and autumn is that they are changing their coats.

One of the indications of a healthy animal is the feel and appearance of his skin. It should be supple, smooth, glossy, and move freely over the subcutaneous tissues. One of the earliest signs of ill-health is often afforded by the skin; the horse, as it is termed, "looks wrong in his coat"; it is either "staring," or else instead of moving freely over the ribs it feels as if glued down to them (hide-bound).

The skin differs in appearance, depending upon its position. Around the lips it is closely attached to the muscular structure below, and the whole feels one compact mass; we also notice that the hairs are here few and fine, but that we have also growing out from the skin long and very fine hairs, commonly known as feelers or whiskers. Behind the angle of the mouth the skin is exceedingly thin and supple, and is nearly the thinnest in the body; over the head and cheeks it is thin and never has fat beneath that part covering the external masseter muscle. On the sides of the neck the skin is still thin, but at the crest where the mane is growing it becomes much thicker, and is subcutaneously much confused with the fatty mane; down the front of the chest and inside of the forearm the skin is particularly thin and very lax; over the scapular region it becomes thicker and more firmly attached below, and over the back and loins we have the thickest skin found; it is also thick down the quarters, but inside the thigh and up to the groin is the thinnest skin covering the body; the skin over the limbs is of medium thickness. If the hair be removed from a horse's body it will be found that the colour of the integument approaches that of the negro; the epidermis is black or bluish-black, excepting in those places where there are white hairs, and here the integument is pink; the colour of the skin in what are usually called grey horses is black or bluish-black.

From what has been said we may conjecture that though the skin of the horse is divided as in man into dermis and epidermis, and contains glands, vessels, nerves, &c., yet these parts will present different appearances depending upon their position in the animal body.

The *corium* consists of a dense network of fibrous tissue, the fibres forming meshes; the latter at the upper portion of the skin are small, the fibres running generally parallel or interlac-

ing so as to form a fine network; as we get deeper into the skin the network increases in size, the bundles of fibres are much larger, and it is evident that they are running in two directions, for some may be seen in section represented as spaces, whilst others may readily be traced up and down, or from side to side. Where the skin is thickest this network of fibrous tissue, amongst which can be detected connective-tissue corpuscles, is sure to be the best developed.

The upper surface of the corium is irregular in outline, forming the papillæ of the skin; the size of these papillæ will vary with the part examined. On the lips they are large, and towards the mouth they become very long indeed, increasing in length until the mucous membrane is reached, where they are succeeded by the very long papillæ which grow from this part (see fig. 1). It is only at the margin of the lips where this extreme papillated condition is observed, for although the whole skin of the lips has a well-developed papillated surface, yet nowhere is it so well observed as here; the papillæ are from ·005 to ·014 of an inch in length, and their width at the base is from ·001 to ·007 of an inch; inside the mouth the papillæ are much longer, and measurement gives them at ·04 inch, and a breadth of ·005 to ·007 inch. The papillæ or finger-like processes are highly endowed with nerve supply, and they correspond with the long finger-like papillæ I have found on the touch extremity of the elephant's trunk. The whole of this papillated surface is covered by a thick and beautifully arranged epithelial layer to be described later on (fig. 2).

Passing somewhat deeper into the corium of the lips we are much struck by the very large amount of voluntary muscular tissue entering into its formation; muscular fibres can be traced running up between the hairs for a considerable distance; below and around the hair-bulbs they are exceedingly numerous, and in parts where the section has been made transversely to the course of the fibres large planes of voluntary muscle are to be seen, presenting in stained sections the most beautiful appearance.

In reality the part beneath the skin of the lips is wholly muscular, broken here and there by hair-bulbs, connective tissue, and glands. In the skin of the wing of the nostril we

also observe a large amount of muscular tissue entering into the formation of the corium, with fibres running up between the hairs. The papillary layer of the corium of the nostril is very regular; there are no long papillæ such as are found on the lips.

The corium of the general surface of the body is made up of the usual fibrous fasciculi. There are no fibres of the voluntary order of muscle, and the papillary layer is small and fairly regular; sometimes the papillæ are single, at others compound. The corium of the skin under the tail is delicate, the papillary layer barely exists; there are but few elevations or depressions on the surface; the usual fibrous reticulum of the corium exists and is well marked. In the mane we have a well-developed corium, and the papillæ here are large, and the majority, instead of being pointed, are square-topped, almost flat on their surface. In the skin of the leg the papillæ are well marked.

The papillæ of the skin are vascular and nervous, but there is no regularity in their arrangement: we do not find the nervous and vascular papillæ alternately placed, as I am informed occurs in some skins.

Epidermis.—The surface of the corium is covered by the epidermis, which can be divided into the usual two layers. The Malpighian rete is well marked throughout, though it requires some manipulation to bring it into view; the cells are columnar and nucleated; they contain a quantity of pigment which in some parts is so considerable as to completely obscure the cells. This is very noticeable in the skin of the lips and under surface of the tail; in the mane we find that this pigmented condition of the Malpighian layer is very much reduced in amount, and is sometimes absent.

The usual arrangement of epithelium occurs, becoming in the stratum mucosum progressively flatter as we reach the surface of the skin. In some parts this is beautifully marked, as on the lips, particularly the inside, where every slight change in shape can be followed with wonderful regularity, from the deep cubical cell to the superficial flat cell (fig. 2). Nuclei can be distinctly seen in the epithelial cells, particularly well marked in that layer just described. Usually we find a certain amount of brown pigment in the cells just above the rete Malpighii, but

is principally in length. In the wing of the nostril the glands are from ·012 to ·02 of an inch in length, and from ·005 to ·006 inch in breadth; on the body they are ·005 inch in length and ·002 inch in width; in the lip, ·01 inch in length and ·004 inch in width; and in the mane, ·04 inch in length and ·01 inch in breadth. There can be no doubt that I have seen branches of nerve supplying the sebaceous glands of the horse.

Sudoriferous glands are usually present in large quantities everywhere; in the lips, mane, and limbs, they are however but few in number. These glands stain easily with gold chloride; they are readily seen in the skin of the neck, where they are numerous and often completely surround a hair-sac. On the general surface of the body the glands are enormously developed, there being a continuous row of them under the hair-bulbs. The ducts of the glands can be readily seen coiling their way towards the surface of the skin. These glands are not numerous in the mane, and in the tail, though plentiful, they are very deep from the surface. In examining the skin of the limbs I had very great difficulty in finding sweat glands; they are few in number, and at one time I thought that none existed. The sweat glands on the general surface of the body lie at a depth of ·055 inch from the rete Malpighii, in width and length they are ·017 inch; the diameter of the tube is ·002 inch. In the nostril the glands are ·022 inch in length and ·012 inch in width, the diameter of the tubes being ·003 inch. Of the many sections made I have never seen the tube of the sweat gland terminating on the surface of the skin, so that I cannot say whether it is spiral as in man or not.

Lymphatic Vessels.—Great difficulty has been experienced in demonstrating the lymphatic vessels of the skin. All I can determine is that we have lymphatic spaces in the upper half of the corium, and that as we get deeper into its structure lymphatic vessels are large and numerous.

Hairs.—Especial attention has been paid to the arrangement of the hairs in the skin of the horse, for I have been anxious to try and determine how those changes which the coat undergoes twice a year are brought about.

The hairs found on the body are best divided into three classes,—(*a*) the tactile hairs (feelers) found on the lips and

muzzle; (b) the temporary hairs on the general surface of the body; (c) the permanent hairs of the mane and tail.

Tactile Hairs.—These hairs are very long, and project out some distance from the muzzle; they run for a considerable depth into the skin, and are enclosed in a globular white or yellow sac quite visible to the naked eye. The hairs are not hollow, nor can any trace of canals be seen; in this respect they differ much from the corresponding hairs which I have found on the trunk of the elephant, and which, I may here add, are also enclosed in large globular sacs. If we make a transverse section of a "feeler," we find that a large round or oval space exists in the subcutaneous tissue for its accommodation (figs. 5 and 6). The external sheath of the hair follicle is made up of fibres taking a circular direction, containing connective-tissue corpuscles. The sheath is ·002 of an inch thick; within this there is a space, often very large, as much as ·06 inch, traversed by prolongations which run from the internal to the external sheath of the hair follicle (figs. 5 and 6). When I first found this space I considered that it was due to portions of the internal sheath dropping out on making the section, but the examination of a very large number of specimens has convinced me that the condition is perfectly natural, and that the internal sheath is never in apposition with the external sheath of the follicle excepting by means of the processes described. In number the processes or prolongations are from ten to twenty, and extremely delicate; their length is from ·006 to ·01 of an inch. They are made up of connective tissue and filled with corpuscles. The internal sheath of the follicle surrounds the vitreous layer; this sheath is also composed of connective-tissue elements, and in width would be about ·007 to ·01 of an inch. Between the external and internal sheaths I have seen portions of sebaceous gland. Next comes the vitreous layer of the follicle, which is extremely narrow, and better seen in transverse than longitudinal sections; within this is the external root-sheath, made up of epithelial cells derived from the rete mucosum; those cells nearest to the vitreous layer are columnar, the others are polyhedral; all have a nucleus; the width of this layer is ·005 of an inch. The internal root-sheath comes next, I am not satisfied that it consists of the two layers described in man, and for accuracy it would be

best to describe it as one layer. It appears to be formed of scales, though in some preparations it appeared vitreous; within this layer is found the hair. All these points are shown in figs. 5 and 6.

If we examine a longitudinal section of these " feelers," we observe that the external sheath of the follicle is derived from the corium; the internal sheath commences at the neck of the follicle, passes under the papilla, which either rests on it or is formed from it, and extends up the opposite side; it is much thicker around the hair-bulb than elsewhere. The external root-sheath is readily seen to be derived from the epidermis; it does not extend down to the hair-bulb. In this section the space between the external and internal sheaths of the follicle is plainly seen, also the prolongations which maintain the hair in position (fig. 5). The sebaceous glands are found at the neck of the follicle, usually above the sac. Such is the appearance of this singular object. Staining with picro-carmine gives admirable results, and we can then see the parts perfectly differentiated. The hair is shown as a yellow body with a dark centre, the internal root-sheath is deep red, the external root-sheath orange, the internal sheath of the follicle delicate pink, with scarlet connective-tissue corpuscles, the external sheath paler, with scarlet corpuscles; the whole presents a most beautiful object. The external sheath of the follicle is highly endowed with nerve supply; gold preparations show a most extensive plexus on the inside of the sheath. The hairs found in these sacs lie at a depth of ·125 of an inch from the outer surface of the epithelium, and are ·008 inch in width. In appearance they present no medulla, and are black or brown in colour. I cannot find that these tactile hairs are in contact with any special nerve-endings, but the extensive nervous supply of the outer sheath of the follicle is quite sufficient to account for their sensibility.

Temporary Hairs.—The sheath in which these lie is different from that of the tactile hairs. Here we have a narrow external follicular sheath on which the hair papilla rests; *there is no internal sheath*, but next comes the external root-sheath of epithelial cells, the external being columnar, the others polyhedral, and all nucleated; lastly, the internal root-sheath, which again appears as a single membrane (fig. 7). The hairs which

fit into these follicles have a cortex and medulla; the cortex is vitreous in appearance, but the medulla consists of irregular spaces filled with pigment. Whilst the latter remains in them the part looks quite black, but when the pigment falls out the spaces are clearly seen (fig. 8). At their extremity the hairs terminate in a point, whilst in the skin they gradually increase in size as we get deeper, until they expand to form the bulb, which is hollow below to accommodate the papillæ. In the hair-bulb there is a quantity of pigment consisting of round black and brown cells, as we pass up the hair the cells decrease in number, until the appearance described above takes its place. The outside of the hair is covered by oblong epithelial scales, which form the internal root-sheath. The colour of the medulla of the shaft depends upon the colour of the horse; in grey horses the medulla is black.

The papilla from which the hair grows fills up the hollow on the bulb, and consists of small round cells enclosed in a membrane which either grows from or rests upon the external sheath of the follicle. I am inclined to the former view.

The hairs on the general surface of the body are shed at regular intervals. If we examine the skin at this time of the year we find the majority of hairs, instead of presenting at their deepest part the usual well-known hair-bulb shape, are conical, and the extremity of the cone appears ragged; the hair has lost to a great extent its pigment, though a few large pigment cells can still be seen on the ragged bulb; the portion of hair in the skin is yellow, and it has lost its medulla. By these characteristics a hair in the process of being shed can be instantly recognised (fig. 7).

The first change which occurs in a shedding hair is that the shaft contracts just above the bulb, and as no more hair is at this time being formed from the papilla, the shaft gradually becomes separated just above the bulb, and the extremity of the hair becomes ragged. The papilla and bulb are now represented by a quantity of cells filled with pigment; the old hair becomes gradually forced up, taking with it the internal and external root-sheath; the cells of the latter spreading under the ragged bulb completely enclose it. In this way it is forced upwards, the distance between it and the papilla gradually

becoming greater. Having got perfectly free from the old hair the papilla now commences secreting again, and we soon see a streak of cells extending above it. These rapidly assume the form of a hair, and we now notice that these hairs are coloured, presenting a great contrast to the colourless shedding hair which is still forcing its way outwards; the new hair rapidly grows upwards, and, pushing its way to one side of the external root-sheath of the old hair, causes the latter to become displaced, and the follicular sheath to bulge accordingly (figs. 7 and 9). Soon the apex of the new hair reaches the side of the old one, separated from it only by the remains of the old external root-sheath, and in a short time it touches the old hair, and the two are then seen lying side by side in the follicle, and the new hair, growing more rapidly than the old one is cast off, soon makes its appearance at the external surface of the skin, and we here have the singular appearance presented *of two hairs growing out of the one follicle* (fig. 9); the old hair gradually reaches the surface and is cast off. The new hairs attain a certain length, and then cease growing. After a few months they lose their vitality, and are replaced in just the same way as described above. Such is the singular method by which the horse sheds his coat twice a year.

On the general surface of the body the hairs have a width of ·0035 of an inch, the medulla being ·003 inch; the internal root-sheath ·0005 inch, the external ·002 inch, the vitreous layer ·0003 inch, and the follicular layer ·002 to ·004 of an inch.

The *permanent hairs* of the body are those of the mane and tail. These have exactly the same coverings as the temporary hairs, the internal root-sheath being single, and the internal follicular sheath absent (fig. 10). Both in the tail and mane the coloured hairs have a well-marked medulla; where there are white hairs in the mane or tail the medulla is either absent or only represented by a black streak. In the mane and tail the hairs which die are recognised by exactly the same characters as the temporary hairs; here, however, we never see the new hair growing alongside of the cast-off one. The width of the mane hairs is ·005 to ·006 of an inch, medulla ·0045 inch, internal root-sheath ·0005 inch, external root-sheath ·003 inch, vitreous layer ·0005 inch, and follicular sheath ·003 to ·004

inch. The hairs of the tail are the widest in the body, being ·01 of an inch.

In the hair of the mane there is a well-marked internal root-sheath made up of oblong cells, which fit into each other most beautifully, and stain deeply with carmine; in some sections these cells are left in the follicle when the hair has fallen out, in others they can be seen closely adhering to the hairs. I have seen this appearance in other parts of the skin, but nowhere so marked as in the mane.

I have not attempted to describe the minute anatomy of the hoof, for this has already been carefully worked out by several able observers. I hope in a future paper to describe the histology of the skin of the elephant.

EXPLANATION OF PLATE VIII.

Fig. 1. Section through the lip close to the mucous membrane, showing the shape and length of the papillæ, and the distribution of the nerves, *n.n.*

Fig. 2. Section through the mucous membrane of the lip, showing the very long papillæ and nerve supply, *n.n.*

Fig. 3. A section through the skin of the leg, showing the distribution of vessels, *v.v.*, to the glands, hair sheaths, and papillæ; the section through the hair is oblique.

Fig. 4. A section through the skin of the side; the sweat glands are very large.

Fig. 5. Longitudinal section through a "feeler" from the lip, showing the follicle and hair sheaths.

Fig. 6. A transverse section through the skin of the lip, showing the "feeler" in position; the muscular tissue in the surrounding parts is very large; at the bottom of the figure some nerves are cut across.

Fig. 7. A section through the skin of the side; the hair on the right is a new one, and its investing sheaths are the same in all hairs excepting "feelers"; to the left of the figure the old pale hair, with its ragged end, is being forced out, and causes the sheath to bulge.

Fig. 8. A section through a hair from the side showing cortex and medulla.

Fig. 9. A section through the skin of the side taken from a horse shedding his coat; two hairs may be seen projecting from the one follicle; the bulging of the sheath is very marked.

Fig. 10. A hair from the mane, showing its investing sheaths; only the sheaths on one side of the hair are drawn; *a* is the hair.

ON THE OBSERVATION OF THE PUPIL AS A GUIDE IN THE ADMINISTRATION OF CHLOROFORM.
By Henry J. Neilson, M.D.[1] (Plate IX.)

In the study of the employment of anæsthetics in surgery, the changes occurring in the size of the pupil have not, I think, received the attention they deserve. The decided variations which take place in that organ are very remarkable. Yet no definite conclusion has been arrived at as regards their relation to the different stages of anæsthesia. In the chapters on anæsthetics in the leading surgical text-books, the pupillary phenomena are quite passed over, or are dismissed with a few words.

Sir Joseph Lister, in his article in Holmes' *System of Surgery*,[2] says :—" The most convenient test of the patient being prepared for undergoing the operation is presented by the eye, not in the size of the pupil, which is inconstant in its indications, but in what is commonly spoken of as insensibility of the conjunctiva."

Erichson describes the modifications undergone as follows :[3]— " The pupil is at first contracted, but afterwards becomes widely dilated and insensible to light, and this is a sign that the administration has been pushed to the furthest limits consistent with safety, and must be suspended till the pupil again responds to light."

Gross makes a similar statement :[4]—" In the second stage, which succeeds imperceptibly to the first, the individual gradually lapses into a state of entire unconsciousness, . . . the pulse and respiration will diminish in force and frequency, and the pupil will become notably dilated."

According to the *International Encyclopædia of Surgery* :[5]—" At first the pupils are variable in their diameter. When anæsthesia is fully declared the pupils are contracted, but if the condition of stupefaction is carried to the extreme, dilatation takes place and persists till death."

Attention was called to this subject in 1874–75 by several articles which were published in the Parisian scientific journals.[6]

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[1] This memoir was presented as a thesis for graduation as M.D. to the Medical Faculty of the University of Glasgow.

[2] Vol. iii. p. 603.

[3] *Science and Art of Surgery*, vol. i. p. 23.

[4] *A System of Surgery*, by Samuel D. Gross, vol. i. p. 566.

[5] Vol. i. p. 406.

[6] " De l'état de la pupille pendant l'anesthésie chirurgicale produite par le chloroforme indications pratiques qui peuvent en résulter," *Progrès méd. Paris*, 1874, ii. 525, par P. Budin ; " Considérations, sur l'état de la pupille pendant la duré de l'anesthésie chloroformique," *Gaz. méd. de Paris*, 1874, iii. 469, par

The most important of these was entitled "Recherches cliniques et experimentales sur l'état de la pupille pendant l'anesthésie chirurgicale produite par le chloroforme."[1] In this paper it was asserted that the condition of the pupil offered a reliable evidence of the degree of anæsthesia produced by chloroform, and was therefore of value as a guide in its administration. The conclusions formulated were these :—

1. The administration of chloroform causes on the part of the pupil a series of modifications which are in relation with the state of the sensibility.

2. During the period of excitement the pupil is dilated.

3. That period being passed, the pupil gradually contracts, but is still sensible to excitations.

4. During the period of profound surgical anæsthesia two constant phenomena are to be observed in the pupil—(1) absolute immobility, (2) a state of contraction.

There is a relation between the absolute insensibility of the patient and the contraction with immobility of the pupil ; between the return to consciousness and dilatation with mobility of that organ.

5. The condition of the pupil is, therefore, able to serve as a guide in the administration of chloroform.

6. Gradual dilatation of the pupil occurring during an operation indicates that the anæsthesia is less profound, and that the sensibility is returning.

7. In operations of long duration, if it be desirable to have the patient perfectly insensible, the chloroform should be given in such a fashion that the pupils remain constantly contracted and immobile.

8. The efforts of vomiting produce dilatation of the pupil, cause the insensibility to pass off, and the patient to awaken. They destroy in part the effect of the anæsthesia.

9. It is important in observing the pupillary phenomena not to confound the true chloroform anæsthesia with the anæsthesia of asphyxia. The latter causes quite different alterations in the pupil.

10. Though the state of the iris is able to serve as a guide for the direction of the anæsthesia, it is unable to give warning of the imminence of accidents.

The pulse, respiration, and general condition of the patient must also be carefully observed by the chloroformist.

These conclusions were disputed and contradicted by Professor Schiff of Florence,[2] and others,[3] who published quite opposite results,

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P. Coÿne ; "De l'état de la pupille pendant l'anesthésie chloroformique et chloralique et pendant less efforts de vomissements," *Gaz. méd. de Paris*, 1875, 45, 67–69, par P. Budin et P. Coÿne.

[1] *Archives de Physiologie normale et Pathologique*, 2d série, ii., Janvier, par P. Budin et P. Coÿne.

[2] "Nota sulla pupilla nella narcosi chloroformica," M. Schiff, *Imparziale Firenze*, 1876, xvi. 363.

[3] "Chloroform and the Pupil," W. H. Winslow, *Phila. Med. Times*, 1876, vi. 270–277 ; *La pupille considérée comme Esthésiometrie*, &c., &c.

but up to the present date the action of the pupil during chloroform anaesthesia is still undecided, if we can judge by the conflicting statements made by the various authors who have investigated the subject. In reviewing the literature, I have only been able to find one article in which the results given by Budin and Coÿne are completely agreed with, viz., a paper written in the Polish language by Dr Storkouski.[1] Professor Westphal[2] of Berlin, writing on the subject of the dilatation of the pupil caused by any irritation made before the patient is deeply narcotised, says, "If one make an individual unconscious by chloroform, a strong contraction of the pupil to a pin point is noticed at the commencement of the same.

Dogiel[3] states that chloroform at first induces contraction and afterwards dilatation of the pupil. Schläger[4] gives, as a result of the observation of 122 cases at the surgical clinique in Göttingen, that in the stage of full anaesthesia, the pupil was completely contracted in 120, and completely contracted with immobility in 119 of these.

It has always been difficult for me to determine the exact moment at which a patient is sufficiently under the influence of chloroform *for an operation* to be proceeded with. The sign of abolition of conjunctival reflex action, which is usually relied on, is very variable; in fact, in the majority of cases, it is altogether misleading. I have also frequently experienced discomfort from the want of a reliable symptom to indicate whether the patient is deeply under the influence of chloroform—a matter of paramount importance for satisfactory administration. And I have never been able to observe the modifications of the pupil during the different stages of anaesthesia which are described in most of the above-quoted works, viz., that it is at first contracted then dilated.

The statements of Budin and Coÿne were so dogmatic, and the results of their experiments seemed so exact, as to make the affair appear very simple. I therefore determined to ascertain for myself whether or not they were reliable, and at the same time, if possible, to form an opinion as to what changes

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[1] "Practyczne wskazówki o zachowaniu sie zrenie pod wpylwem srodkow znieczulajacych," *Gaz. lek. Warsawa*, 1876, xx. 289–291.

[2] "Ueber ein Pupillenphänomen in der Chloroformnarkose," *Arch. f. Path. Anat.*, &c., Berlin, 1863, xxvii. 409–412.

[3] "Ueber die Wirkung des Chloroforms auf der Organismus der Thiere im allgemeinen und besonders auf die Bewegung der Iris," *Arch. f. Anat. Physiol. u. Wissensch. Med. Leipz.*, 1866, 231–415.

[4] "Die Veränderungen der Pupille bei Chloroformnarkose," *Centralbl. f. Chir. Lei z.*, 1877, iv. 385.

really occurred in the size of the pupil during the action of chloroform.

As House-surgeon in the Royal Infirmary of Glasgow, I was in the habit of administering chloroform almost daily, and in January 1885 I commenced to observe and note particularly the modifications in the pupil under its influence. For this I had the permission of my superior, Mr Clark, for whose encouragement and assistance I am deeply grateful. A year later I had the opportunity of following up my observations by a series of experiments on dogs. The following are the more important details of a few of these observations and experiments :—

a. CLINICAL OBSERVATIONS.

Chloroform was in all cases given on a thin piece of flannel, stretched on a light wire mask; the fluid was poured from a drop bottle, and the pupil was kept under observation from the commencement of the administration till complete consciousness returned.

1. *J. A., æt.* 11.—*Periosteal Abscess.*—The pupil, which was moderately wide before commencing, dilated to its fullest extent during the first few inhalations. It continued in this state for a few minutes, and the patient after struggling and moaning a little became gradually quiet. The conjunctival reflex being already suspended, the operation was commenced, but at the first insertion of the knife the boy showed signs of pain, and the incision was therefore delayed, while the chloroform was further pushed. In about four minutes from the commencement of the administration the pupil began to contract, and soon reached a very small size. The operation was then resumed, the patient lying perfectly still, and the pupil quite motionless. No more chloroform was given, and the condition described lasted till the operation was over, and the wound dressed. The patient was then aroused, and the pupil was observed to dilate simultaneously with his first manifestation of feeling.

The points noted in this case were (*a*), dilatation of the pupil during the initial stage; (*b*), contraction which gave way to dilatation when the patient was irritated; (*c*), contraction with immobility coincident with perfect anæsthesia; (*d*), a condition similar to that under (*b*); and (*e*), dilatation as sensibility returned.

2. *M. M'D., æt.* 17.—*Scraping out Necrosis of Tarsus.*—The pupil dilated on commencing administration, but in about three minutes

began to contract, and gradually became smaller, the patient at the same time becoming perfectly quiet and motionless. Operation was proceeded with, and did not cause any movement of the iris. The chloroform being withdrawn after a few minutes, slight dilatation of the pupil was noticed, immediately followed by struggling of the patient, and other signs of returning consciousness. Administration was recontinued, until the pupil was again fully contracted. It remained so till the conclusion of the operation, but dilated quickly and completely on the patient being aroused.

3. *J. S.*, *æt.* 40.—*Perineal Section.*—Pupil small at commencement. After a little chloroform had been given it dilated slightly, and remained so for a minute or two, during which time the patient struggled and showed signs of excitement. As he became quiet the pupil contracted to pin-head size. This condition lasted for several minutes, and no more chloroform was given; the pupil then dilated slightly, the patient at the same time beginning to moan. Chloroform was then renewed, and the pupil soon again contracted, remaining so till the patient was aroused after completion of the operation.

In these two cases also, dilatation was succeeded by contraction (which did not last long, but was maintained by the re-administration of chloroform), and dilatation again on the return of consciousness.

4. *R. S.*, *æt.* 57.—*Abdominal Section.*—Pupil dilated in a few seconds, and remained so for four minutes. The patient did not struggle, the conjunctival reflex was abolished, the limbs were flaccid, and anæsthesia seemed complete. The operation was commenced, and had so far proceeded that the peritoneum was exposed before any contraction of the pupil could be observed. On contraction commencing, the chloroform was withdrawn. The pupil became of pin-head size, and remained so for many minutes. It then relaxed, and at the same time the patient showed slight symptoms of feeling; a few drops more chloroform were therefore given. This caused the pupil at once to contract again. After another considerable period the pupil dilated more widely than before, and immediately afterwards the patient vomited. At this point administration of ether was commenced, and the pupil did not contract under its influence.

In this case perfect insensibility was produced with the pupils still dilated; but it is to be remarked that the patient was in an exhausted condition, owing to intestinal obstruction of several days' standing, and this probably modified the action of the chloroform upon the iris. The dilatation of the pupil preceding the effort of vomiting is noteworthy, but the full interest of the case was spoiled by the substitution of ether in the middle of the operation.

5. *J. W., æt.* 12.—*Excision of Metatarsal Bones.*—Slight dilatation soon after starting, followed very rapidly by contraction. At the first insertion of the knife the pupil dilated widely, and a considerable quantity of chloroform was given before it began to contract again. It remained contracted till near the end of the operation, when slight dilatation took place, immediately after which the patient became sick and vomited.

This had the effect of almost completely arousing him from his state of anæsthesia and stupor.

The effect of sickness upon the pupil is here the most interesting point, its general behaviour under the anæsthetic being as in the first three observations.

6. *J. S., æt.* 14.—*Amputation of Thigh.*—Several hours previous to the operation eserine had been dropped into the right eye, consequently its pupil was contracted, while the left was considerably wider. Dilatation was observable in both after the first few inhalations of chloroform, though the movement of the right iris was limited on account of the action of the eserine. The left pupil remained dilated for about four minutes, and was variable when the patient was irritated by pinching, &c., then it began to contract. The boy seemed now deeply under the influence of the agent, the pulse was very weak, and the respiration slow and shallow. Commencement of the operation had not the least effect on the pupils, both of which were strongly contracted—the right one (eserine) to a pin-head size. The narcosis was perfect during the whole operation, which lasted about ten minutes, and the pupils remained strongly contracted and immobile. As the dressings were being applied the left pupil dilated, and half a minute later the patient became sick and vomited. This had the effect of completely dilating the pupils (the right one not very much owing to the eserine), and seemed to awaken the boy, as immediately afterwards he began to cry out, and exhibit other signs of suffering.

The action of eserine, it will be noted, is merely to increase the contraction and limit the dilatation of the pupil. The effect of sickness in dilating the pupil, and causing the immediate return of consciousness, is also seen in this case.

7. *P. C., æt.* 26.—*Resection of Bones of Leg for Ununited Fracture.*— Atropine had been applied to the right eye, so that its pupil was widely dilated. The left pupil was in a contracted state. Immediately after commencing administration the left pupil dilated; no change was observable in the right. The patient's lips were cyanotic, and his respiration unsatisfactory from the beginning; the chloroform had therefore to be given with extra caution. In about five minutes the pupil became contracted, but the patient was not yet thoroughly narcotised, because on the insertion of the knife the pupil

at once dilated, and he struggled faintly.   A little more chloroform caused contraction to return, but it did not last long, and soon gave way to dilatation.   A few drops more chloroform were given till the pupil began to contract, and so on throughout the operation, which lasted over half an hour, the chloroform mask being applied when the pupil dilated and withdrawn when it contracted.   In this manner the patient, though never deeply under the influence of the drug, was kept sufficiently still for the purposes of the operation.   The pupil dilated completely on his return to consciousness, and a few minutes later returned to the contracted state it showed before the commencement of administration.   No change could be noticed in the right pupil, its action being evidently thoroughly paralysed by atropine.

8. *M. H. æt. 7.—Hip-joint Abscess.*—Right pupil previously dilated by atropine.   Left pupil, which was of medium size before commencing, dilated with the first few inhalations of chloroform, the child crying and struggling violently.   In three minutes contraction set in, and the operation was proceeded with.   The pupil remained contracted and motionless for about one minute, then began to dilate, and in a few seconds the child groaned and struggled.   A little more chloroform caused the pupil again to contract, and rendered the patient insensible to pain.   The same phenomena were repeated several times, ,viz., contraction coincident with perfect narcosis, and dilatation as recovery took place.   After the operation, as the child awakened, the pupil dilated to its fullest.   No change took place in the eye which had been treated with atropine.

From these two observations it will be seen that no modification is brought about by chloroform in a pupil paralysed by atropine.

9. *P. M'B., æt. 24.—Amputation of Thigh.*—Pupil dilated in half a minute after commencement, but not to any extent, the patient taking the anæsthetic very quietly.   In four minutes the pupil began to contract.   In five minutes it was fully contracted, but manipulation of the limb caused dilatation.   Some more chloroform was given and the pupil became immobile; the operation was then begun.   The pupil kept in the contracted condition for three minutes, the patient breathing quietly and showing no sign of feeling.   It then dilated gradually, and the patient immediately afterwards began to struggle.   More chloroform being administered the pupil again contracted and remained so for a few minutes, then behaved as before.   When the flaps were being stitched the pupil dilated widely, and in a few seconds the patient vomited.   This had the effect of bringing him back to consciousness, and he asked if the operation was over.   No more chloroform was given, as very little remained to be done.

The dilatation of the pupil preceding vomiting, and the effect of the latter in bringing about the return to sensibility, are the chief features of this case.

10. *S. C., æt. 6 months.—Cauterisation of Nævus.*—Pupil dilated with the first few inhalations, and was just beginning to contract when the cautery was applied. This produced dilatation again and slight struggles, but the anæsthesia being quite sufficient for the purposes of the operation, no more chloroform was given. The pupil remained of large size.

This case is interesting, as serving to shōw that extreme contraction of the pupil is not caused by chloroform unless the drug is pushed till complete anæsthesia is produced.

11. *W. S., æt. 12.—Removal of Enchondromata.*—Pupils small. In about thirty seconds the pupil dilated,—not widely, but quite distinctly. The boy took the anæsthetic very quietly, without the slightest struggle. In three minutes the pupil contracted. The conjunctiva had been for more than a minute perfectly insensitive, but the patient was not yet thoroughly narcotised, for on manipulating the hand he groaned, and the pupil dilated. When the pupil had been contracted for about a minute, but still responded to excitations, it suddenly dilated, and in a few seconds the boy vomited. This brought him completely from under the influence of the chloroform, and he became quite conscious. When the sickness had passed off, the administration was recommenced, and in two minutes the pupil was strongly contracted. The operation was now commenced, the pupil remaining perfectly still and fixed in its contracted condition. A minute later it dilated, but a few drops of chloroform caused it to contract again. This state was kept up throughout the operation, chloroform only being given when the pupil relaxed and taken away when it contracted again. On one occasion no chloroform was given when the pupil began to dilate, with the result that the patient in a few seconds moaned, struggled, and interrupted the operation till he was made unconscious again. The administration was then conducted as previously. While the wound was being stitched, the pupil, which had already slightly relaxed, dilated widely, and immediately afterwards the patient vomited. This awakened him and no more chloroform was given.

This case demonstrates the practical advantage of the observation of the pupil with a view to keeping the patient in a state most suitable for the operation, without narcotising him dangerously. When the pupil was strongly contracted, by noticing its first indication of dilatation and immediately administering some chloroform, the patient was kept perfectly motionless, but when this was omitted, he became sensitive and interrupted the progress of the operation.

12. *J. G., æt. 16.—Ovariotomy.*—Pupils small before commencing. They dilated widely in one minute, the girl crying and struggling. In three and a half minutes the pupil began to contract, the patient

at the same time becoming perfectly quiet. The conjunctival reflex was abolished, but the pupil dilated on any excitation by pinching, &c. Five minutes from commencement of administration the pupil dilated widely, and in a few seconds the patient vomited. This aroused her, and she spoke as if conscious. Chloroform being continued, the pupil in about one minute contracted, and in one minute more was of pin-head size, and did not respond to irritation. The operation was commenced without causing any change in the size of the pupil. The pupil was kept in this state of atresia for fifteen minutes, by giving a few drops of chloroform whenever the iris showed signs of relaxing. The pulse being at this time rather weak, no chloroform was given, though the pupil was beginning to dilate. In thirty seconds from the first sign of dilatation the pupil dilated quickly to its fullest, and the patient immediately vomited. The operation was interrupted, and the girl became semi-conscious and muttered incoherently. Chloroform was resumed, the pupil again contracted, and the patient became perfectly quiet. This condition was maintained for twenty minutes, when the operation being nearly finished, the chloroform was removed. The pupil soon began to dilate, and, just as previously, in a few seconds dilated widely, the patient vomiting once more. This awakened her so completely that more of the anæsthetic had to be given for the wound to be stitched. She went under its influence and the pupil contracted as before. The same phenomena were further noticed on the chloroform being withdrawn when the operation was finished, viz., wide dilatation of the pupil immediately followed by vomiting and awakening of the patient.

In this operation the patient was only thoroughly motionless when the pupil was contracted and immobile. Whenever the pupil was allowed to dilate slightly, it rapidly did so to its full extent, and sickness followed in a few seconds. This had its usual effect of arousing the patient. The conjunctival reflex was abolished from a few minutes after the commencement of administration until the end, with the exception of a few seconds after each occurrence of sickness.

b. EXPERIMENTS.

As it was difficult, if not impossible, on account of the existing state of the law, to carry out a series of such experiments in this country, I performed them at Vienna in the university laboratory for experimental pathology, under the supervision of Professor von Basch. I proceeded in the following manner:— In order to avoid the influence of the nasal reflex, and for greater control over the amount of chloroform to be given, tracheotomy was in all cases performed and the drug adminis-

tered through a tracheal tube. An apparatus was constructed by which the chloroform vapour could be shut off instantly and fresh air admitted, with an arrangement for regulating the admixture of chloroform and air.

The blood-pressure in the carotid was traced on Ludwig's kymographion, the time recorded in seconds, and the exact moment of change in the size of the pupil marked by means of Marey's electro-magnetic signalling apparatus.[1]

In nearly every case three separate administrations of chloroform were given, with intervals for recovery intervening, and at the third the anæsthetic was pushed till death resulted. Tracings were taken in connection with every experiment performed, but as they all show similar results, only one is annexed as a type of the others.

It will be noticed that a few experiments were tried, on the suggestion of Professor von Basch, which, though beyond the province of this paper, deserve to be mentioned, viz., the injection of strychnine with a view to resuscitation. This alkaloid, while failing several times either through too large or too small a dose being given, was successful in reanimating two dogs (see experiments 3 and 5).

Experiment 1.—*Young Terrier of Middle Size.*—Wide pupils. 10.50 A.M., administration of chloroform commenced. Full dilatation of pupil took place in forty-five seconds, accompanied with struggling of dog. Half a minute later contraction followed, the animal becoming perfectly quiet and insensible. A knife stuck into various parts of the body caused no alteration in the pupil, nor did variations in intensity of light. After another half minute, the blood-pressure being very low (see Chart), natural respiration was re-established. The blood-pressure in a few seconds began to rise, and in about a minute and a half pupil dilated. A knife was then stuck into the dog's leg, which caused immediate complete dilatation of the pupil and struggling of the animal. An interval of ten minutes was now allowed for the dog to recover. At 11.6 A.M., the pupil resting in a medium state, chloroform was recommenced. Immediate violent struggling of the dog and dilatation of the pupil took place. A complete state of dilatation was not reached, but in half a minute contraction began, and soon the pupil was reduced to a very small size. The-blood pressure had come down more rapidly this time and was now very low (see Chart), so normal respiration was re-established. The revival of blood-pressure took longer than at the first administration, but when it had risen some-

[1] See Dr M'Kendrick's *Outlines of Physiology*, pp. 91, 355.

what (see Chart), gradual dilatation of the pupil was observed and
the dog again became sensible. Another interval of ten minutes was
given. At 11.24 A.M. chloroform was recommenced. Pupil widely
dilated in fifteen seconds, accompanied by struggling of animal. It
did not begin to contract for more than a minute, and reached com-
pletion slowly. Chloroform was still pushed, and two minutes later
the pupil dilated, immediately after which respiration ceased, and the
blood-pressure was reduced to *nil* (see Chart). Without having
recourse to artificial respiration, about $\frac{1}{60}$ grain of strychnine was
injected into the jugular vein, which caused pulse and respiration to
return within a minute. These were both gradually increasing in
strength, when suddenly they began to get weaker, and quickly ceased
altogether (see Chart). It was not till then noticed that the chloro-
form apparatus had not been withdrawn when respiration ceased and
free access of air was therefore prevented, so that the dog had really
been poisoned a second time. Another dose of strychnine was
injected, but it was too late, as it had not the slightest effect.

This experiment demonstrates the relation between the state
of the blood-pressure and the modifications in the pupil, con-
traction each time occurring when the pressure had fallen a
certain length, and dilatation when it had risen again. It also
illustrates the rapid poisoning which ensues when the chloro-
form is pushed after the pupil has become strongly contracted.

Experiment 2.—Small Young Terrier.—Wide · pupils. 9.55 A.M.,
chloroform administration commenced; immediate dilatation of pupil,
accompanied by violent struggling of the animal. The pupil re-
mained completely dilated for a few minutes, then contracted slightly,
and in half a minute more dilated again. The dog was still strug-
gling. A leak was at this moment discovered in the tracheal tube,
on account of which the dog was inhaling scarcely any chloroform.
After readjustment of the apparatus, chloroform was given again at
10.2 A.M. Complete dilatation followed in half a minute, with wild
struggles. The dilatation remained for two minutes, the struggles of
the animal gradually subsiding; then contraction commenced, and
reached completion in half a minute. The dog by this time was per-
fectly still, and the insertion of needles caused no reflex action. As
in the previous experiments, the contraction of the pupil was coinci-
dent with a considerable fall in the blood-pressure, and therefore half
a minute later natural breathing was re-established. After the dog
had been allowed a few inhalations of fresh air, the pupil quickly
dilated, and the struggling of the animal recommenced. Ten minutes'
interval of natural breathing was now allowed, during which time the
pupil varied according to the dog's struggles, irritation by light, &c.
When undisturbed it rested in a medium state. At 10.19 A.M. the
administration of the anæsthetic was recommenced. Rapid and com-
plete dilatation accompanied by struggling, followed in a minute and
a half by contraction with perfect quietude, the latter coincident as

before with fall in blood-pressure. One minute later the chloroform was again withdrawn. In a minute and a half pupil began to dilate, with at the same time returning signs of consciousness. During the period of strong contraction the animal was irritated by needles and knives, but the pupil remained immobile. After dilatation had begun, the same irritations caused sudden increase, with signs of feeling. Another ten minutes' interval for natural breathing having been given, chloroform was commenced at 10.35 A.M. for the third time. The result was immediate dilatation, not complete, and at once followed by contraction. This time there was very little struggling of the animal. The chloroform was still continued, and in one minute the pupil dilated suddenly, and remained fixed and immobile in its dilated condition. A little later, respiration, which had become gradually slower, altogether ceased. Injection of strychnine had no effect.

The same phenomena were observed in this experiment as in the last. One point of special interest is noted at the commencement, viz., the absence of contraction of the pupil when chloroform was not administered in a sufficient dose, and its prompt contraction when that error was rectified. The relation of general sensibility to the state of the pupil is also shown. When dilatation occurred in response to peripheral irritation, the general anæsthesia was found to be insufficient; but when the pupil became perfectly motionless, and irritation brought about no change, the narcosis was found to be complete.

Experiment 3.—*Young Dog.*—Small pupils. 9.59 A.M., administration commenced. Sudden and rapid dilatation of pupil complete in twenty-five seconds. In one minute it began to contract, and this condition also reached its full extent very quickly. The dilatation was accompanied by the usual excitement and struggling of the dog; as the contraction took place, these gradually subsided, and soon altogether ceased. After pursuing the administration for one minute with the pupil strongly contracted, it was stopped and fresh air supplied. Thirty seconds later the iris began to relax, and shortly afterwards strong dilatation took place. Ten minutes' natural breathing were now allowed, and the pupil regained its original condition, viz., a state of moderate contraction. At 10.16 A.M. chloroform was again given. Immediate and rapid dilatation, followed as before in about half a minute by contraction. Struggling occurred during dilatation, and perfect stillness as the pupil became contracted. The blood-pressure having fallen very low, and respiration being unsatisfactory, chloroform was almost immediately withdrawn and fresh air admitted. As in every other previous instance, the blood-pressure began at once to rise. The pupil remained strongly contracted for two minutes, when excitation by needle-pricking caused dilatation and signs of feeling. Other ten minutes' interval having elapsed, at 10.30 A.M.

administration was recommenced. Again immediate dilatation was observed, accompanied by struggling of the dog. This time the dilatation took about forty-five seconds to reach its utmost, and it began to contract thirty seconds later, reaching its narrowest limit in thirty seconds more. The chloroform was continued with the pupil in its state of strong contraction for one minute and a half, when respiration suddenly stopped, and the pupil dilated exactly at the same moment; the blood-pressure became much lower, and the pulse very slow. Chloroform was removed and artificial respiration practised for a minute and a half without any effect. One-fiftieth grain of strychnine was then injected into the jugular vein. In a few seconds the dog gave a convulsive gasp, then began slowly to breathe. As this occurred the pupil again became contracted, and remained so for a few minutes. It then dilated, and at the same time the dog showed signs of feeling. The blood-pressure, which had gradually risen, was now as high as before commencing the experiment. In about five minutes tetanic spasms suddenly set in, the pupil dilating very widely. These continued for a minute or two, and the dog seemed to be dead, but he gradually came round again, and in the space of five minutes was respiring quietly.

The remarkable effect of strychnine as a means of resuscitation is the chief new feature of this experiment.

Experiment 4.—Small Lap Dog.—Thin and delicate. Vessels very much thickened by strumous deposit. 10.15 A.M., chloroform commenced. Immediate dilatation of pupil accompanied by wild struggling of dog. In about a minute the animal became perfectly quiet and unconscious, no response being made to irritations, but the pupil was still widely dilated. In about two and a half minutes from first inhalation the pupil began to contract, and advanced rapidly to a very minute size. As the blood-pressure was now very low, and breathing slow and laboured, the chloroform was taken away and fresh air supplied. This did not cause the usual revival of the blood-pressure, and in about half a minute the pupil dilated, while at the same time respiration stopped and the pulse failed. Artificial respiration was tried, and strychnine injected into the jugular vein. The pulse returned faintly, but was not accompanied by respiratory effort, and soon ceased again. The time which elapsed before the pupil was completely contracted was longer than usual, and the dog had therefore a larger dose of chloroform. This fact, taken with the apparently weakly condition of the animal, probably accounts for its death.

This case illustrates the danger of pursuing the administration of chloroform even for a few seconds after the pupil has become strongly contracted and motionless.

Experiment 5.—Small Young Terrier.—Pupils medium size. 10.41 A.M., chloroform commenced. In twenty-five seconds dilatation of

pupil, which increased till it was complete. In thirty-five seconds more the pupil began to narrow, and continued to do so till it was in a strong state of contraction. The dilatation was accompanied by struggling of the animal, and the contraction with gradual loss of consciousness. The latter was coincident with fall in the blood pressure, as in all the previous experiments. The pupil being now strongly contracted, chloroform was withheld and fresh air admitted. In one minute the pupil began to dilate. In another minute it was fully dilated, and the dog struggled again as before. During a ten minutes' interval the pupil returned to much the same state as it was in before starting the experiment. At 10.58 administration was recommenced. In about a minute the pupil began to dilate, but did not do so to any extent, as contraction set in almost at once. In two minutes from the time of starting pupil was completely contracted, and, the blood pressure again being low, fresh air was substituted for chloroform. Pupil did not dilate for six minutes, and even then, notwithstanding vigorous irritations with needle and knife, no sign of feeling was manifested till another minute had elapsed. Ten minutes' interval of natural breathing was again allowed, and at 11.20 A.M. chloroform was recommenced. Within thirty seconds dilatation of the pupil began, and within one minute was complete. It remained so for two and a half minutes, the blood pressure gradually subsiding, then the pupil began to diminish and was fully contracted in another minute. After a few moments the chloroform was taken off. The pupil remained strongly contracted for six minutes, and then dilated in response to irritation. Another interval of ten minutes having elapsed, at 11.41 A.M. chloroform was again given. Within a minute pupil was completely dilated, within two minutes it contracted, and within three minutes was in a state of strong contraction. The administration was still continued, the pupil remained contracted for four and a half minutes, then suddenly dilated, coincidently with stoppage of respiration and marked sinking of blood pressure. Fresh air was then admitted and strychnia injected, the dog being to all appearances dead. Slight return of pulse followed immediately on the injection of strychnine. Artificial respiration was employed for about a minute, when spontaneous respiration took place. This gradually increased for about five minutes, when it became spasmodic; in other five minutes the tetanic state began to pass off, and breathing again became natural. After this the animal progressively recovered, the tracheotomy and carotid ligature wounds were stitched, and the animal left breathing vigorously with occasional slight tetanic symptoms.

The tardy action of the chloroform as compared with the former experiments is here to be noted, and the action of strychnine in causing return of respiration and pulse.

Experiment 6.—*Very Small Dog about Two Months Old.*—Pupils wide. 9.40 A.M., chloroform commenced. Immediate dilatation, followed in about one minute by slight contraction, which gradually

became stronger till complete. Chloroform being removed in about one minute the pupil dilated and the animal began to struggle. Having allowed a quarter of an hour's normal respiration, chloroform was again given at 9.55 A.M. Pupil dilated after a few inhalations, and in about a minute began to contract. When it had become very small and motionless, the anæsthetic was removed, and fresh air admitted. Pupil remained strongly contracted for five minutes, when it dilated, and the dog showed signs of sickness. This aroused him, and struggling began. After another interval of ten minutes, at 10.20 A.M. administration was recommenced. Immediate dilatation of pupil, followed very shortly by contraction which rapidly became complete. After a few seconds, the blood pressure being extremely low, the chloroform was removed. The blood pressure at once began to rise, but the pupil did not relax for fifteen minutes. The dog, which throughout the stage of contraction remained perfectly quiet and insensitive to any kind of excitation, now commenced to struggle, and responded to irritation. After ten minutes' interval chloroform was renewed. The initial dilatation was again followed quickly by contraction. Administration was still continued, and in one minute the pupil dilated suddenly, and at the same moment the dog ceased to breathe.

The modifications in the pupil are here the same as in the previous experiments, viz., dilatation with excitement, contraction with perfect anæsthesia, and dilatation with recovery or with asphyxia caused by an overdose.

These clinical observations and experiments, which are selected from a series of over fifty, represent what happened in the large majority of cases. In a few the phenomena were somewhat variable, but could always be accounted for by exceptional circumstances. It is to be noticed that the results of the clinical observations are less definite than the experiments, for the obvious reason that in the former case the object of the operation and the patient's life were the chief considerations, while in the latter the material could be handled as was thought most desirable for the special purpose. The rapidity of action of the chloroform in the dogs is very striking, and is to be accounted for by the method of administration. The same is the case in the human subject when chloroform vapour is introduced directly to the lungs through a tracheal tube.

From my investigations, I have no hesitation in saying that the conclusions of Budin and Coÿne, above quoted, are for the most part correct, excepting the one (7), from which they advise that the pupil be kept in a state of atresia with immobility for

a long period. That this direction is not only impracticable but dangerous is proved by all my experiments; for in every case where the chloroform was pushed for very little over a minute after the pupil had become strongly contracted, sudden dilatation occurred, and the animal almost at the same moment ceased to breathe. From this state of apparent inanition it was possible to resuscitate the dog by the usual means, but it is very doubtful if this could be accomplished were the drug administered in the ordinary way, because in the experiments artificial respiration could be promptly and effectually applied through the tracheal tube, an arrangement not usually applicable in operations; and, even with all this advantage, in one or two instances the attempts to revive the animals entirely failed.

With regard to the practical value of observing the pupil when giving chloroform, it must be admitted that this is considerably reduced by the fact that there is no change (so far as I have seen) which gives warning of the imminence of accidents in time to admit of their prevention. The dilatation which is seen when the drug is pushed after the pupil has become strongly contracted is the dilatation of asphyxia, and occurs, I am afraid, too late for any hope of resuscitation. I have never pursued the administration far enough in the human subject for this dilatation to be produced, because in all cases when the pupil became contracted and immobile the narcosis was profound, and I considered it risky to continue the chloroform. The danger in so doing is proved by what happened in the experiments described, when the chloroform was continued after the pupil had become strongly contracted. But the observation, which, notwithstanding many statements to the contrary, I think is unquestionably reliable, that modifications occur in the pupil bearing a constant relation to the state of sensibility, surely proves that it is well worth observing, especially when this can be done without at all preventing proper attention to other symptoms of importance. The watching of the respiration and the pulse, which are doubtless the best indications of the effect produced on the individual, and therefore of vital importance for safe administration, does not in many cases furnish evidence of the state of sensibility, in regard to which I hold the observation of the pupil to be of greatest assistance.

The sign usually relied on, viz., the insensibility of the con-
junctiva, is by no means a satisfactory test, for in many cases
conjunctival anæsthesia is established long before the patient
can be said to be under the influence of the drug. By observ-
ing the pupil, a person giving chloroform can tell at once when
the effect of the drug on the sensibility is on the wane, because
the pupil then begins to dilate and react to excitation by the
knife, &c. Noticing this he can, by the administration of a few
drops more chloroform till the pupil contracts again, prevent
the occurrence of struggling and interruption of the operation.
In this way he can keep the patient in the state most suitable
for the satisfactory performance of the operation without nar-
cotising him more than is necessary. The amount of chloroform
required to maintain a state of anæsthesia is much less than
that required to put a patient under its influence several times;
and as it is admittedly a dangerous drug, the less administered
the better, especially in operations of long duration. And by
allowing the patient partially to recover, one runs the risk of
the occurrence of sickness and vomiting, which is always an
awkward and often a dangerous accident. In the absence of
such a guide as the observation of the pupil, the chloroform
must be given in a rather haphazard way, dosing the patient
till narcosis is profound, perhaps too much so, then interrupting
the operation till the danger is averted by arousing him or
waiting until signs of feeling, such as struggles or a cry of pain,
give indication for more chloroform.

The observation of the pupil also furnishes a fair indication
of the effect produced by chloroform. On consulting the Chart
annexed, the relation of the size of the pupil to the state of
blood pressure will be at once noticed. Contraction of the
pupil only occurred when the blood pressure had fallen con-
siderably, and, on removal of the chloroform, dilatation only took
place when the pressure had risen a certain height. As reduc-
tion of the blood pressure was pronounced by the Scientific
Grants Committee of the British Medical Association[1] to be
one of the chief dangers in chloroform administration, the
presence of a sign by which the occurrence of that important
condition can be recognised must be of practical value. In

[1] *Brit. Med. Jour.*, December 18, 1880.

conclusion, I have to state as the result of my investigations the following opinions:—

1. The effect produced by chloroform on the pupil is at first dilatation, varying in degree and duration, then contraction as the narcosis becomes profound, and dilatation again when the sensibility is returning. If the administration be still continued, with the pupil strongly contracted and motionless, the pupil will also dilate, but in this case more suddenly and completely, and will be coincident with a state from which it will be difficult or impossible to resuscitate the patient. This latter is the dilatation of asphyxia.

2. So long as the pupil dilates in response to excitation by pinching, &c., the patient is not sufficiently narcotised for the operation to be proceeded with, unless the latter is slight, and does not require complete anæsthesia.

3. When the pupil becomes strongly contracted and immobile, no more chloroform should be given until it begins to dilate again. If, then, further anæsthesia be required, a little more chloroform should be given, till the pupil again contracts.

4. The occurrence of sickness causes dilatation similar to, but more sudden than, that which happens when sensibility is returning, and the efforts of vomiting have the effect of arousing the patient.

It is not the purpose of this paper to undervalue in the smallest degree the indications afforded by the respiration and circulation in the administration of anæsthetics, but rather to supplement these by a sign which can easily be observed in conjunction with them. The observation of the lips, which is the most convenient method of watching both respiration and circulation, can be attended to at the same time as the state of the pupil. While I consider, therefore, that attention to the former is of first importance, I at the same time believe the latter to be of valuable assistance, and worthy of observation by every one who administers chloroform.

[Plate IX. is the Chart referred to in the text.]

AN ACCOUNT OF SOME EXPERIMENTS WHICH SHOW THAT FIBRIN - FERMENT IS ABSENT FROM CIRCULATING BLOOD. By JOHN BERRY HAYCRAFT, *Physiological Laboratory, University of Edinburgh.*

THESE experiments support the view, first advanced by Sir Joseph Lister, that the blood has no spontaneous tendency to coagulate.

When blood is withdrawn from an artery or vein and received into a cup it coagulates in a few minutes. Within the cup it is obviously in a state of rest, it loses temperature, and it comes in contact with the air. It might naturally be supposed that these altered conditions sufficiently account for the coagulation. This does not appear to be the case.

1. *A short account of Hewson's experiments.*

More than a century ago Hewson[1] demonstrated that the blood included within a vein ligatured at two places remains fluid often for many hours, although it is, of course, in the condition of rest. In other experiments he showed that cooling *retards* coagulation, while increase of temperature slightly accelerates it. Unfortunately, however, he fell into the error of supposing that it was contact with the atmosphere which caused coagulation. This has been amply disproved by subsequent experimenters.

2. *The theory of Sir Astley Cooper and Turner Thackrah, commonly called Brücke's theory.*

About the beginning of the present century some very important work was done by Sir Astley Cooper and Turner Thackrah.[2] I have been unable to obtain a copy of their work, and am obliged in consequence to speak of it on the authority

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[1] *An Experimental Inquiry into the Properties of the Blood,* 1771.
[2] *An Experimental Inquiry into the Properties of the Blood,* 1834.

of Brücke, who quotes from it. Quotations taken from Brücke are, however, of especial interest, as will shortly appear.

"It was Sir Astley Cooper," he says, "who made the first successful experiments in support of the view that the influence which keeps the blood fluid arises from the surrounding tissues, that is to say, from the heart and walls of the vessels." He induced Turner Thackrah to examine the subject at greater length, and this observer published his results in an essay which obtained a prize,[1] "and never was one more deserved," remarks Brücke. Thackrah's chief experiment consisted in excising the vein of a recently killed animal containing blood, which remained fluid for an hour or more. When, however, the blood was poured into the veins of an animal killed the day before, it clotted in the usual time—less than fifteen minutes.

Thackrah was therefore led to endorse the view of Sir Astley Cooper, "that the vital or nervous influence is the source of the blood fluidity, and its loss the cause of coagulation."

In the above quotations it is manifest that Cooper and Thackrah alluded to the vital or nervous influence of the vascular wall, and not to any action of the central nervous system— the brain and spinal cord. Brücke, however, seems to think that they did, and hastens to show by a conclusive experiment that the brain and spinal cord have no action at all upon coagulation. He killed a terrier dog, removed the brain and spinal cord, with the result that the blood remained fluid in the systematic veins for some hours, as long, in fact, as if the dead animal had retained its nervous system. But this experiment was palpably superfluous, for Thackrah had actually cut out a vein containing blood, and had removed it from the body. It was very improbable, therefore, that he could have thought that the nervous system had any action on an excised vein. The only excuse for the publication of this experiment of Brücke's was that Thackrah had used the words "nervous or vital," which, taken alone without the context, might well convey an ambiguous meaning. In an essay of the highest scientific value in many respects Brücke adds nothing to the work of Cooper and Thackrah,—indeed the merit of his paper is destructive rather than constructive. Nevertheless, and although his essay was actually written in competition for the fifth triennial prize founded by Sir Astley Cooper himself,

[1] "An Essay on the Cause of the Coagulation of Blood," *Medico-Chirurgical Review*, 1857, p. 191.

he has been given by posterity the full credit of propounding a theory he himself most courteously ascribes to another.

I shall term the view that I now proceed to state more fully, the theory of Cooper and Thackrah. It is as follows:—The living arterial wall, or, more strictly speaking, the living lining of a blood-vessel, prevents or inhibits blood from coagulating. When this fluid comes in contact with any matter other than the lining of a healthy artery or vein it coagulates.

3. The view of Sir Joseph Lister that the blood has no inherent tendency to coagulate.[1]

Sir Joseph Lister subsequently brought forward the suggestion, that perhaps after all the blood has no inherent tendency to coagulate if unaltered and undisturbed. In this case it is unnecessary to assume that the blood vascular walls restrain coagulation, and we have only to invest ordinary matter, such as glass, porcelain, &c., with the property of causing or inducing coagulation of blood in contact with it. In support of this view many suggestive facts were adduced. For example, blood within large vessels, such as the excised jugular of an ox, will retain its fluidity for many hours. In this case it is difficult to understand how such a large mass could be controlled by an area of vascular wall so small relatively.

His most important experiment, which I shall briefly describe, is the following :—He removed part of the jugular vein of an ox, having previously ligatured it in order to retain the blood. He then held it vertically, opened its upper end, introducing with great care a glass tube, which was fitted above with a stop-cock. When the tube had filled with blood he turned the stop-cock, inverted the tube, drew off the vein, and tied a cap of gutta percha over the tube to prevent evaporation. The blood was thus transferred to the tube from the vein, and in such a manner, all shaking having been avoided, that the greater part of the blood had not come in contact with the glass. It was now in a vessel of ordinary matter, but with this peculiarity as compared with the blood shed into a basin, that only the circumferential parts of the mass had come in contact with the solid wall. After the lapse of some hours, Lister found that there was a crust of clot coating the inside of the tube, but within this to the centre the blood still remained fluid. He concludes "that by this simple experiment was demonstrated incontrovertibly the fact that healthy blood has no spontaneous tendency to coagulate, and,

[1] Croonian Lecture, *Proceedings of the Royal Society of London*, 1863.

'therefore, that Brücke's idea of the fluidity of the blood being due to an action of the walls of the vessels upon it is erroneous."

If Sir Joseph Lister's views have not been universally accepted, it is probably because many observers have maintained that fibrin-ferment is produced, and is normally present in circulating blood. If this is the case it is indeed difficult to understand why that fluid does not clot within the body, unless, indeed, it is prevented from so doing by the vascular wall. Others maintain, too, that the body is capable of destroying the ferment when it is present in dangerous quantities. Under these circumstances no very definite opinion can be given, and the whole subject is one which will repay fresh study. Undoubtedly, in Sir Joseph Lister's experiment the circumferential parts of the blood-column in contact with the glass tube clotted almost immediately, forming the lining crust which he described. The rest of the blood subsequently remained in contact with this blood-clot and preserved its fluidity, and one may naturally ask, whether after all this experiment demonstrated anything more than the fact that one may replace one vital tissue by another, with a result which is similar in both cases.[1] It is well known that blood surrounded by healthy living tissue other than the lining of a blood-vessel or a clot often remains fluid for some time. Indeed, it was Professor Lister himself who demonstrated that blood received directly into the peritoneal cavity of a frog remains uncoagulated for a considerable period. The problem is therefore still involved in some difficulty, and it must be restated as follows:—Either blood of itself does not tend to coagulate, or it does tend to coagulate unless it is prevented by the living vascular wall, the endothelium of the peritoneal cavity, or other serous membrane, or the blood-clot with which it is in contact. Why does blood, which when in contact with glass or wood coagulates in five or ten minutes, remain fluid for so many hours when held within a cup formed of a vein, a blood-clot, or of a serous cavity ? I have endeavoured for several years to find some solution of this

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[1] Professor Lister himself states (op. cit., p. 24):—" I have expressed the opinion I have formed that clot must be regarded as living tissue in its relation to blood. It is no doubt a very peculiar form of tissue, in this respect, that it is soft, easily lacerable, and easily impaired in its vital properties.'

problem, which is certainly an open one, and which is treated as such in the works of most physiologists. No true answer to this question can be accepted which does not explain the essential difference between the physico-chemical properties of the lining of a blood-vessel and those of an ordinary solid. The use of the words "vital," "nervous," or any other term devoid of definite scientific meaning must be stringently avoided.

4. *Contains an account of a casual experiment performed before the present investigations were systematically undertaken.*

A series of very curious phenomena are exhibited by supersaturated solutions of neutral and other salts. If a salt be added to boiling water until it ceases to dissolve any more, and if the vessel containing it, which should be scrupulously clean, be corked, and the fluid be allowed to cool, the salt does not crystallise out, but remains in solution. If, however, air containing dust particles be blown into the flask, crystallisation at once occurs. It would seem that the salt requires the presence of "points of formation" in order that it may pass from the liquid to the solid condition. There is, too, an analogous case in the condensation of watery vapour, for if a flask deprived of dust particles and containing vapour be cooled, the vapour will not condense; whereas, immediately on the entrance of a cloud of dust particles into the vessel condensation occurs. It occurred to me that possibly the coagulation of blood outside the body might be due to the action of dust particles, and the reason why it did not coagulate within the vessel was, that no points for the deposition of fibrin were present there.

I accordingly received blood fresh from a vein into a carefully cleaned and exhausted tube of glass. The arrangement that I found to be most convenient was devised for me by my friend, Dr Nicol. It may be briefly described. A piece of clean tube, sealed at one end, was drawn out at the other end into a capillary bore. It was then exhausted by means of a Sprengel's pump, and closed by means of a gas-flame in the centre of the capillary part. The exhausted portion was then broken off. A vein was laid bare, the capillary portion of the tube thrust through its coats into the blood. The point was broken off within the vein by the fingers pinching from outside. The blood then rushed in and filled the tube, and the

capillary extremity was closed. Although this experiment was repeated with great care, the blood was found to coagulate in the usual way, and with the usual rapidity, the absolutely clean surface of the glass being sufficient to induce it in spite of the absence of dust particles.

5. *A method is suggested which will enable the investigator to obtain blood neither in contact with solid matter nor with the arterial wall.*

The question why the blood remains fluid within the body seemed then absolutely to depend upon some difference between the action of the arterial wall and a smooth clean solid. For some time it seemed impossible to follow up the investigation to any advantage. It occurred to me, however, that if it were possible to suspend a drop of blood in space, so that it should be neither in contact with the arterial wall nor with any solid matter, the whole question could at once be solved. If under these conditions the blood coagulated, we should have to look for some restraining action in the arterial wall, and Cooper's view would be correct; but if it remained fluid under these circumstances, it would evidently have no inherent tendency to clot. Now, it is possible to suspend a fluid, if not in space, yet in another fluid, with which it does not mix, and with which it may hardly be said to come in contact. A drop of oil can float in water—it preserves its globular shape at any rate under certain conditions of temperature—and its molecules do not come in contact with the water molecules. This is due to its surface tension. The fluid, whether suspended like a hanging drop of water in air, or like the oil in water, has what is termed a physical skin surrounding it. If, then, we can obtain a fluid with which blood does not mix, and which is heavier than blood, it will be possible to suspend it on the fluid out of contact with any solid matter. Now blood has practically the same surface tension as water, and it is a little heavier, its specific gravity being about 1·055. Among fluids having a different surface tension are therefore oils of various kinds, vaseline, paraffin, chloroform, and ether.

6. *Experiments with the blood suspended between chloroform and paraffin, performed in* 1883.

Some of the first experiments I performed in the year 1883 were with chloroform and paraffin oil.

The former fluid was poured into a glass vessel, and over this a layer of liquid paraffin; the blood was obtained—a very bad method —from the finger tip. The finger was rendered turgid by winding a pocket-handkerchief around it from base to tip; it was well oiled to prevent the blood from clinging to it, and a needle was then pushed rapidly through the skin. The drops of blood fell into the paraffin, and settled down between the paraffin and the heavier chloroform. In every case another drop was received on a glass slide for purposes of comparison. In one experiment, blood which clotted on the glass slide in six minutes had not completely clotted in the paraffin and chloroform in fifty minutes. In another, blood which had clotted on the slide in ten minutes had not completely clotted in the paraffin and chloroform in forty-three minutes.

I was much encouraged by these striking results, for it seemed not improbable that, by improving the method (obviously a very imperfect one), the blood might be preserved in a fluid state outside the body for a still longer period. While pursuing this aim I discovered the curious action of the saliva of the leech in preventing coagulation.[1] This seemed an investigation which promised to lead to very definite results, readily obtainable, and with a probable bearing on the point I was working at. I accordingly left my experiments with surface tension for a time, returning to them in the spring of 1885.

7. *An improvement in the method of obtaining blood is introduced.*

Unsatisfied for obvious reasons with the method I had used for obtaining blood, I tried another and a better method.

The heart and lungs of a sheep which had been bled to death were removed from the thorax. Holding the trachea, so that the lungs were left hanging from it, the heart was cut away. In this way the two lungs, each containing a little blood in the smaller pulmonary vessels, were obtained for the experiment. None of this blood had passed out of the vessels, nor had mixed with any other blood which had touched even the knife used to sever the pulmonary arteries, for in the almost bloodless animal and in the position in which the lungs were held these vessels were empty. A short piece of glass tubing was prepared, three-quarters of an inch long, and a little less in diameter than the pulmonary artery. The free cut end of the artery was pulled through it, and everted over it and tied in that position

[1] *Proc. Roy. Soc. Lond.*, xxxvi. 478.

with string. The inner coat of the vessel was in all cases turned up over the glass at least a quarter of an inch. The lung could then be squeezed, the aperture of the artery hanging downwards. The exuding blood dropped therefore straight into the oil or paraffin without touching anything except endothelium.

These experiments gave very much the same results as the previous ones, and in consequence of this I began to suspect that chloroform, and perhaps the paraffin, might affect the blood chemically in spite of their surface-tensions being so different from it. I accordingly obtained purer paraffin than before, and injected some of it into the artery of the lung, carefully squeezing the vessel from time to time, so as to mix it with the blood. In three cases this was tried, and in two the blood in contact with the paraffin was fluid and unchanged when examined twelve hours afterwards. In the third the experiment had failed owing to carelessness, the blood having been allowed to overflow for a single moment, and having clotted in consequence. In the case of chloroform, however, clotting occurred in the course of about one hour, and the blood was quite changed in character, being very transparent indeed.

I had not then read Schmiedeberg's interesting work on the action of chloroform on blood, which, indeed, had been but recently published, or I should never have used that fluid for my experiments. The paraffin oil mixing with the blood within the blood-vessel had failed so completely to induce coagulation, that I felt hopeful that could the blood be *supported* on a surface equally as inert, coagulation might be indefinitely postponed. My difficulty, then, was to get a fluid of a specific gravity higher than that of blood to replace the chloroform. Mercury and bisulphide of carbon were of little use; the surface tension of glycerine did not permit of its use in the experiment.

8. *An attempt is made to support a drop of blood on bubbles of egg-white.*

I then tried bubbles of egg-white blown from an ordinary clay pipe, and received on the edges of the rims of large pill-boxes.

A row of these pill-box rims was prepared, with fibres stretching across them. Drops of blood were carefully placed upon them, and they were covered at once by a moist chamber. The blood, however, clotted in a very short time, almost as fast as the drops set aside for comparison, probably due to dust particles and slight evaporation.

9. *An attempt to support blood on liquid paraffin is not successful on account of air and dust.*

Just as a greased needle will float upon water if it be carefully placed upon its surface, so will a drop of water remain upon the surface of oil or paraffin.' The slightest shake, and the needle and drop of water will sink. This same fact may be observed in the case of blood, although this fluid is rather heavier than water.

I accordingly dropped blood from a lung—and I may say that every experiment was repeated several times—very carefully on to the surface of paraffin. The little globules generally remained for hours. The vessels containing the oil and the paraffin were always placed in moist chambers. But coagulation invariably occurred very soon, nearly as quickly as the blood placed on one side for comparison. It clotted first on the surface exposed to the air, and then spread gradually downwards. This latter fact convinced me that were it possible to get the blood surrounded with paraffin alone, and not exposed to the atmosphere and dust, coagulation outside the body would be considerably postponed.

10. *Blood is supported on solid paraffin, and on greased mica plates.*

I accordingly hollowed out a solid block of paraffin, smoothed the surface of the cup, and poured liquid paraffin into this. The success of this experiment was more satisfactory ; the blood resting between the liquid and solid paraffin remained fluid for over an hour, but coagulated in less than ten minutes when poured out into a glass vessel. I took some very smooth plates of mica, smeared them with grease, and placed them in the bottom of a vessel containing paraffin. The blood drops which settled on the plates in many cases clotted in less than an hour, but were often fluid for longer than that period. On one occasion they were perfectly fluid for three hours. This, then, was a much more satisfactory result.

11. *Semi-fluid paraffin is injected into a venous cup and mixed with the blood.*

Even the most successful of the experiments hitherto performed were not all that could be desired. Those described in the last paragraph gave results which could not be relied on. For instance, if some half-dozen drops of blood were each

received on mica plates under paraffin, one or two would clot in twenty minutes, others in an hour, and perhaps one or two would remain fluid for a longer period. Evidently there was some factor producing coagulation which had not been considered, and was not constant in its action. Undoubtedly this factor was the presence of particles of dust and dirt. Although carried out with care and cleanliness, the experiment was performed in an atmosphere which was not dust-free.

In the experiment shortly to be described, the blood was held within a venous capsule; the entrance of dust particles with the paraffin introduced within it was practically avoided.

Some fluid paraffin thickened with vaseline was filtered into the pulmonary artery of a sheep. The vessel was so arranged that it formed a cup. The paraffin was then mixed with the blood, so that some of the blood globules were entirely surrounded by paraffin. In this case one can hardly suppose that the wall of the vessel could affect the blood through intervening layers of paraffin. In this experiment the blood *did not* coagulate for many hours. The blood was examined the morning after the experiment and was quite fluid.

To my own mind the experiment was satisfactory in showing that the arterial wall plays a negative part, and that blood is a fluid which, when not in contact with solid matter, if it tends to coagulate at all, does so very slowly indeed. It is natural to suppose that a particle of dust may initiate a clot which may spread through a large mass of blood. A dust particle may be as large as a white corpuscle, and may cause it very readily to break down. When the blood was dropped from the artery into the paraffin and sank down on the greased mica plate, it is probable that it would have come in contact with a few dust particles. This may have taken place in its passage through the air, as it touched for a moment the surface of the liquid paraffin, and, finally, when it touched the greased plate, which was probably covered with dust particles. It was more natural at any rate to conclude that the dust particles produced the very slow coagulation observed out of the body, than to suppose that the arterial wall inhibited the coagulation of blood through the intervening paraffin.

12. *Experiments of Dr Freund.*

When subsequently engaged (autumn 1885) in some experiments to be afterwards described, a short notice of the work of Dr Freund appeared in the *Times* :—

It was here stated "that this observer had retained blood in a permanently fluid condition outside the body by the using of an expedient preferable to the leech-saliva method of Dr Haycraft of Edinburgh. His method consisted in receiving blood directly into a vessel smeared with vaseline and covered with a layer of paraffin."

I had already done practically the same with inferior success, which I had ascribed to the unavoidable presence of dust particles, which I only succeeded in avoiding when the paraffin and vaseline had been filtered straight into a vein and mixed there with the blood. Anxious to ascertain the method he had used, I wrote to him, and received a very courteous reply, containing the following description of his method:—

A cannula well greased with vaseline was fitted to a vein. The blood flowed straight into the vessel containing vaseline covered with paraffin, the other end of the cannula dipping into the fluid. In this way contact with the air was avoided. On repeating these experiments with the greatest care, I failed to keep the blood entirely fluid for longer than three to four hours. By this time the corpuscles had subsided and coagulation commenced first at the periphery.

If a large quantity had been used (50 c.c.) the central portion was fluid when examined next morning. I have, therefore, never been able to keep blood perfectly fluid outside the body for more than four hours, and I believe this is due to the unavoidable entrance of dust particles.

Freund's method gives better results than my own experiments in which blood was dropped from the inverted vein into paraffin, unless, indeed, working with large quantities of blood, he failed to notice the coagulation which in my experience forms after an hour or more at the periphery of the mass. The experiments, however, which in my own hands have given the most satisfactory results, have consisted in filtering a viscid mixture of vaseline and paraffin directly into a vein. In this case the dust particles may be avoided, and the blood often remains fluid for more than twelve hours.

13. *Contradictory opinions are held by physiologists as to whether or not any fibrin-ferment is found in circulating blood.*

Let it then be granted that blood has no tendency to coagulate within the body. We are at once led to the investi-

gation of those changes which the solid matter in contact with blood induces in it, bringing about its coagulation outside the body. Coagulation is produced by the action of a ferment upon a globulin called fibrinogen. The ferment in all probability is produced by the white corpuscles. It is generally believed that foreign matter causes the white corpuscles to break down and set the ferment free, which is then capable of transforming the fibrinogen into fibrin. Now the question arises, Is this process of corpuscular disintegration continually going on to some extent in the body during life ? is the ferment present in circulating blood plasma ? A statement is found in the works of most physiologists, that when blood is shed from a vein directly into alcohol and then examined little or no ferment is found. If, however, the blood be kept even for a few seconds in a vessel of ordinary matter, and then transferred into alcohol, a large amount may be obtained. No one doubts that solid matter causes a great increase of the ferment after the blood has left the body; we have therefore to discuss the truth of the statement "that little or no ferment is present in the circulating blood received directly into alcohol." This has been refuted, and statements of an entirely opposite character have been advanced. Thus Jakowicki and Birk, working in Schmidt's laboratory,[1] maintain that the ferment is found in circulating blood, and, moreover, that it is more abundant in venous than in arterial blood. To account for this latter statement they suggest that in the capillary circulation a number of the white corpuscles are continually breaking down.

When blood is received into a saturated solution of sulphate of magnesia the corpuscles subside, leaving a clear supernatant plasma. If this be diluted with water, or, still better, if the salts be dialysed out, the plasma will coagulate, showing that ferment is present (Johannes Müller).

Edelberg, another pupil of Alex. Schmidt, states that in febrile and inflammatory affections a large quantity of circulating ferment is present. It is well known that in septic fever this may exist in sufficient quantity to produce spontaneous coagulation within the circulation. It is evidently then a moot

[1] "Recherches sur le rôle physiologique et pathologique des leucocytes du sang par M. Alex. Schmidt," *Arch. de Phys. Norm. et Path.*, 1882, p. 513.

point whether the ferment is present in normal circulating blood or not, but it seems to be present in pathological conditions. In my opinion it is the want of exact knowledge on this point which makes it so difficult to assign to the arterial wall the rôle it plays in relation to coagulation. If it is certain that the ferment is not present in circulating blood, then evidently from this point of view alone the theory of Sir Joseph Lister may be accepted, for blood certainly cannot coagulate without the presence of ferment. The belief that the corpuscles are breaking down, slowly it may be, within the body, and constantly setting free the fibrin ferment, has fostered, I believe, more than anything else a belief in Cooper's view. It is but natural to look for something which will restrain the breaking down, or at any rate restrain the effects which would follow the accumulation of anything more than a minimum quantity of ferment within the circulation. To endorse the view that there is something antagonistic to coagulation within the body may be cited the following experiments, likewise the fruits of research in Schmidt's laboratory (op. cit., p. 522). A quantity of ferment was injected into the veins of a cat. This increased for a time the amount of circulating ferment, which after a few hours returned to the normal quantity.

If larger quantities were injected, febrile symptoms, with accelerated respiration, increase of temperature, vomiting, tenesmus, and death, were produced. In this case extensive coagulation had been produced within the body.

Having finished my experiments with surface tension, I attempted in the summer and autumn of 1885 to determine the nature of the destructive or eliminative action of the body on fibrin-ferment. According to Schmidt, as before stated, the ferment injected into the circulation may almost disappear after a few hours. It is conceivable that it may be eliminated from the system, or oxidised or changed in other ways, and this may take place in the blood-vessels or in special glands. If ferment is present in normal circulating blood, then it must either be destroyed by the influence of the vascular wall, to some extent at any rate, or it must be incapable of acting when in small quantity. The reason for this assertion is the fact that circulating blood may be kept fluid sometimes for two days in an

excised vein, where it is solely in contact with vascular endothelium. Now, I am convinced that the smallest quantity of ferment will eventually coagulate a large volume of blood. This had been brought forcibly to my notice by the unfortunate results of many experiments. In those experiments in which the lungs of sheep were used for the purpose of obtaining blood, it was found that the momentary contact of an instrument with the smallest area of the surface of the blood was certain eventually to coagulate the whole mass. In this case the smallest amount only of ferment could have been set free. In experiments subsequently to be described hydrocele fluid containing fibrinogen is shown to coagulate in a time which varies inversely with the quantity of ferment present. Its coagulation may take place in a few minutes or several hours. If ferment is normally present in circulating plasma we must suppose that it is destroyed in some way by the arterial wall. My experiments, in which blood was kept fluid for hours when surrounded by paraffin, render it very improbable that *any* ferment is present in normal circulating blood. It will be well, however, to approach the subject from another point of view, in order to settle the question with more direct experiments.

14. *It is shown that the vascular wall is not capable of secreting any soluble matter which can prevent coagulation.*

A quantity of salted blood was prepared by receiving the blood of a sheep into one-third of its volume of a saturated solution of magnesium sulphate. If this salted blood, which remains permanently fluid, be sufficiently diluted, it will coagulate. Now, the coagulation of a portion definitely diluted will take place in a very definite time indeed, so that if five portions be measured off with a carefully graduated pipette, and diluted with say exactly ten volumes of water, and if, further, each specimen be under similar conditions of temperature, &c., then they will coagulate all together to the minute. It is then easy with this medium to investigate the action of substances preventing or retarding coagulation in any way.

The lung of a sheep was washed out with normal salt-solution (·75 per cent.) at a temperature of 38°, until it flowed in a colourless

stream from the organ, which was from time to time subjected to careful massage.

About a pint of normal warm salt-solution was then passed and repassed through the vessels of the lung, in all twelve times. Three portions of the salted blood were each diluted with ten volumes of this normal salt-solution passed through the lung. They coagulated in thirty-nine minutes. Three portions of blood were each diluted for comparison with a similar quantity of ordinary normal salt-solution. They coagulated in forty minutes. Three portions of salted blood were diluted each with fifteen volumes of normal salt-solution which had been passed through the lung. They coagulated in twenty minutes.[1]

The result of this experiment was, therefore, conclusively to show that nothing of a soluble and diffusible nature, capable of preventing coagulation, is secreted by the blood-vessels. Blood contained within them would have remained fluid long after the experiment had been concluded, and yet they gave to the salt solution nothing which had any effect in postponing the coagulation of a diluted plasma, even for a minute. Indeed, it seemed almost inappreciably to hasten it; but this may be explained, as will afterwards be seen, on the supposition that the normal salt-solution extracted from the pulmonary vessels some few white corpuscles which had not previously been washed away.

15. *A solution of ferment is not destroyed when injected through blood-vessels.*

The experiment was then varied in a way which would bring the blood-coagulating ferment directly in contact with the arterial wall. The lower limbs of a dog were washed out most carefully with warm salt-solution, the solution leaving the vessels in a colourless stream. A portion of the solution of blood-coagulating ferment in 8 per cent. salt solution was diluted with water until the salt reached the amount present in the normal salt-solution. This was then injected into the blood-vessels of the lower limb again and again, in all about twenty times. During this process the muscular tissue of the limbs retained its vitality, responding to electrical stimulation.

The coagulating power of this portion of ferment solution was then compared with the other portion which had not been passed through the vessels. This was accomplished by mixing them with equal volumes of hydrocele fluid, which, containing fibrinogen but no ferment, does not clot until the latter is added.

1. A portion (3 c.c.) of the solution passed through the vessels mixed with an equal volume of dilute hydrocele fluid clotted in ten

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[1] Three portions of salted blood when diluted with the (comparison) salt-solution, coagulated in just over twenty minutes.

minutes. A similar volume of the solution which had not been passed through the blood-vessels coagulated an equal volume of diluted hydrocele fluid in ten minutes.

2. A portion (3 c.c.) of the solution passed through the vessels mixed with half its volume of hydrocele fluid clotted in seven minutes. A similar portion of the other ferment coagulated half its volume of hydrocele fluid in seven minutes.

In this experiment, as in the previous one, the solution which had been injected seemed rather to hasten than to retard the clotting. It was, however, to a very slight degree, not hastening it by a minute. This was due to the ferment solution bringing away a few corpuscles from the vessels, for I afterwards found that normal salt solution injected through three or four times caused the hydrocele fluid to clot in ten hours.

Those experiments, to my mind, demonstrate that the vascular system is neither capable of secreting any fibrin-ferment destroying substance, nor has it any direct power of destroying any fibrin-ferment. In the case of Schmidt's injection experiments, the fibrin-ferment must either have been eliminated from the system or destroyed within some organ. If, then, the vascular wall does not destroy fibrin-ferment, and if a normal quantity of ferment will produce coagulation, it is highly probable that no ferment is found in normal circulating blood.

In that case, therefore, it is not to be supposed that the corpuscles are constantly breaking up in the vessels, setting free the fibrin-ferment. They are possibly destroyed solely in the blood-glands. We have therefore to suppose that the blood does not coagulate, because the ferment or other factor is not produced at all, while the blood remains within the vessels.

16. *The accuracy of the experiments of those investigators who have attempted to prove that circulating blood contains free ferment is very questionable.*

After the experiments detailed in this paper, I had little doubt that the only conclusion at which it was possible to arrive was, that circulating blood contains no free ferment. If any be present, it is shut up in the white corpuscles which are not constantly breaking down in the circulation as is supposed. Schmidt maintains that there are two kinds of white corpuscles. One kind alone breaks down, and forms the fibrin-ferment.

Those experimenters who had obtained ferment from circulating blood by receiving it directly into say alcohol or sulphate of magnesia had, in all probability, not been careful enough to prevent the fluid from coming into contact with the margin of the wound or foreign solid matter.

An experiment performed in 1883 had taught me to consider blood as a fluid in which coagulation may most easily be produced by apparently the most trivial cause.

A vein capsule was opened, and a small portion only of the blood withdrawn for a second by a syringe, and then quickly returned, with the result that the blood clotted in ten minutes, whereas the blood in a similar capsule, taken from the same animal, did not coagulate in ten hours. My experiments with the lungs of sheep, which had often failed from want of manipulative skill on my part, fully corroborated this, and, still more, the following fact which came under my notice. I had occasion in a subsequent experiment to excise several veins containing blood. The bullock, after having been killed, was bled in the usual way. This was performed by thrusting a knife into the thorax through the root of the neck, and severing in all probability both veins and arteries at the base of the heart. An incision was then made over the upper part of the external jugular vein. It was ligatured at its middle, and then blood was squeezed into it by pressure on the upper part of the neck. An upper ligature was finally applied. In the two cases in which this plan was adopted, the blood coagulated in the vein within ten minutes. I was obliged therefore to ligature the vein, including the blood which I required, before bleeding the animal at the root of the neck. In the twelve cases in which this was done, the blood remained fluid for a day or more without exception. Inasmuch as the veins were well provided with valves, one can only suppose that in those cases in which the blood coagulated, part of it at any rate had been within the arteries at the root of the neck when the knife passed through them, and had come in momentary contact with it, and had passed outwards through the capillary circulation into the veins. At any rate, the instantaneous contact with the knife, or the wound that the knife had made, had been sufficient to change the blood entirely. It had now the power to coagulate, and probably contained free fibrin-ferment. If, now, a cannula be placed in an artery, and the out-flowing blood received into a cup containing alcohol, or a solution of a neutral salt, it will certainly come in contact with foreign matter before it has mixed with these fluids. No doubt, this was the method adopted by previous observers, and even if ferment is not present in circulating blood, it will be found in the blood they examined. Such experiments have, in fact, to be performed with very special care, in order to arrive at satisfactory and decisive results.

17. *An attempt to obtain clear plasma free from corpuscles, which has not come in contact with foreign matter, in order to see whether it contained free ferment.*

Instead of receiving blood in the ordinary way from a vein into a vessel cooled to the freezing-point, I obtained an excised vein full of blood, and suspended it in ice.

The corpuscles, however, did not subside, so that on tapping the upper part of the vein blood and not plasma was obtained. This was repeated three times with similar results, the blood of the ox being used. I was not able to obtain the blood of a horse, which is preferable. This method was accordingly relinquished. I then obtained a long venous capsule full of blood, and placed a ligature around it so as to separate it into two cavities, each containing blood. The upper one was emptied and partially filled with a saturated solution of sulphate of magnesia. The ligature was then unfastened, and the remaining blood allowed to mix *within the vein* with the saline solution. I then rapidly filtered the mixture. The filter papers were carefully moistened with a saline solution. The first filtrate was clouded by a few corpuscles, and was passed again and again through the same filter. A perfectly clear, slightly tinted, plasma was then obtained. Plasma obtained from filtering salted blood mixed in a vessel with the saline solution, without using the precautions I have described, coagulates when diluted with water or when dialysed. Portions of this plasma, however, diluted with two, four, and eight volumes of water, remained perfectly fluid for a week, after which time the fluid putrefied. Another portion was placed in a dialyser, and the water in the other vessel was repeatedly replenished. The plasma became in consequence considerably diluted, and the greater part of the sulphate was removed. It remained perfectly fluid. The experiment was repeated twice with precisely similar results. Of course the point in this experiment was to mix the blood with the neutral salt solution *within* the vein, not to withdraw it from the vein through a glass tube, and then mix it.

The conclusions that I would draw from these experiments are the following :—

1. Blood does not tend to coagulate within the body; and when it clots within a cup it is not because it is then withdrawn from influences which restrain its coagulation, but because the surface of the cup induces it to clot.

2. No free ferment is found within circulating blood plasma, and, probably, white blood corpuscles do not break down in the blood-vessels under normal circumstances. Their dissolution is probably entirely in glandular structures.

3. White corpuscles, probably, are not constantly breaking up even in the glands, inasmuch as blood may be retained for so long a time surrounded by paraffin in a fluid condition, showing that their life-history is not so short as was supposed.

4. If injected blood-ferment disappears from the circulation, it is because it is destroyed in glands or eliminated from the system.

5. Solid matter induces coagulation by causing some change in the white corpuscles, leading to the setting free of fibrin-ferment, which previously had either remained stored up within them, or which they produce spontaneously when in contact within the foreign matter.

In conclusion, I may state that my interest in this matter was first awakened during a lecture delivered by Sir Joseph Lister to his class in Edinburgh. If I have ventured to criticise any part of the work of one of the most admired teachers of my student days, it is with feelings of the greatest satisfaction that I find my own results so fully endorse a view that he was the first to propound.

Obviously these investigations only lead us to the threshold of the still more interesting and important inquiry, How does a chemically inert solid particle of matter induce a coagulation which is capable of spreading to an extent only limited by the quantity of blood in contact with it ?

COMPARATIVE DATA FROM 2000 INDIAN CRANIA IN THE UNITED STATES ARMY MEDICAL MUSEUM. By R. W. SHUFELDT, M.D., C.M.Z.S., *Captain, Medical Corps, U.S. Army, &c.*

IT may be remembered that I published in this *Journal,* April 1886, an account, with figures, of a Navajo skull, obtained at Fort Wingate, New Mexico. But the description of a single human skull, although important in some aspects, means but little in others, especially where racial characters, comparative cranial capacities, and similar data are to be taken into consideration. Now, at the time I came into possession of the skull in question, I was removed by many hundreds of miles from any collection of human crania, and would have been quite at a loss to obtain any such data of the kind I refer to, had it not been that my library contained a copy of the *List of the Specimens in the Anatomical Section of the United States Army Medical Museum,* by George A. Otis, of the Medical Corps of the Army.

This *List* catalogues the human crania contained in that museum, which, as we know, is one of the most extensive of the kind in existence. As I was in Dr Otis's section in the museum for some time before I entered the medical corps of the army, and subsequently had charge of a section there myself, I personally had the opportunity of seeing much of that very work done, and can attest to its being prosecuted with the greatest possible care.

In the preface to the *List* we find the following memorandum for our information:—"Metrical measures are employed as most convenient for the greater number of anatomists occupied with these studies. In explanation of the various abbreviations employed, it may be stated that instead of the conventional signs for the male and female sexes, the letters *M.* and *F.* are used; *c.* stands sometimes for *circa* and sometimes for centimetres or cubic centimetres; *L.* indicates the greatest longitudinal diameter, measured from the glabella to the most prominent part of the occiput; *B.* signifies the breadth between the points of the parietal bones widest apart; *Cap.* refers to the internal capacity, measured by No. 8 shot; *H.* denotes the height, measured by calipers, from the middle of the anterior border of the foramen magnum to the most elevated point on the sagittal suture: *C.* refers to the circumference, taken by tape mea-

sure, in a plane including the glabella, occiput, and most prominent
lateral points ; *Z. d.* refers to the zygomatic diameter ; *F. a.* refers to
facial angle.   In accordance with the nomenclature of Dr J. Barnard
Davis, *cranium* signifies the entire bones of the head and face ; *cal-
varium*, the same bones without the lower maxilla ; *calvaria*, the
bones of the skull alone." These points and abbreviations will hold
good in what follows in the present article.

The *List* brought the collection down to the year 1880, at which
time specimens of the skulls of the vast majority of our North
American Indians were represented in it, and to an extent of a couple
of thousand or more.

As to the manner in which these specimens were catalogued in the
List, I present the following example :—

26. California Indians.

1. (85.) *Calvarium.—F.* æt. *c.* 50, *Cap.* 1265 c.c., *L.* 171 mm., *B.*
141 mm , *H.* 130 mm., *I.* f. m. 44, *L. a.* 340 mm., *C.* 498 mm., *Z. d.*
136 mm., *F. a.* 74°.   Presented by Professor Joseph Henry, Smith-
sonian Institution.

In my paper above referred to, I gave some comparative data from
this Catalogue, which contained an account of eight Navajo skulls of
the same sex and almost of the same age as my specimen.   In a
subsequent paper, October 1886, I described and figured the skull of
a Navajo child, and also utilised the material which the Catalogue of
the Army Medical Museum contained.   In the following year I
availed myself of the information contained in this Catalogue in pre-
paring a description of three Apache Indian skulls which had come
into my possession, and the description was published, with figures,
in this *Journal*, July 1887.[1]

As my observations on these crania, and the value of the
averages taken from the authoritative data in the Museum
Catalogue, have been favourably received in several anthropo-
logical quarters, I have been encouraged to prepare a more
extended table of these averages obtained by similar methods
from the same source.   The collection not being before me at
the present writing, I can add no special descriptions of the
individual specimens, nor is it my object to do so; it is my
aim, however, to give the reader some idea of the number and
character of the specimens of the crania of North American
Indians in this Museum at the time the *List* was published in
1880, and to formulate a " Table of Averages," so far as the
material will admit.   Anatomists, ethnologists, and others can

[1] Owing to my residence at Fort Wingate, New Mexico, being so far away from
the printer, I cannot always obtain a proof to have it corrected before the paper
is printed off.   I may take this opportunity, therefore, of stating that in my
paper on the skull in the Apaches, fig. 3 is a profile of the same skull as in fig. 2,
so that (3) (fig. 3) on page 534 should be deleted.

then employ this Table for the comparison of any single Indian skull they may possess, with the data therein recorded.

It is not my intention in the present article to take into consideration the skulls of the Esquimaux, of the Mound Builders, or of the Indians from Alaska or those of the skulls of " Unknown Indians" mentioned in this Catalogue of 1880, but I may do so on some future occasion. Where sufficient material seems to justify, I will endeavour to present in the subjoined "Table of Averages" data from female as well as male skulls. Such a comparison, it is believed, will lend additional interest to the compilation.

Two series of numbers are used in the *List*: the one in the *List* itself, in the Table of Contents, and placed *before* the names of the tribes, which numbers correspond with the order in which the skulls are presented in the body of the work, or in the order of the sections in which they are catalogued ; these numbers are retained below, and stand *before* the names of the tribes both in the " Table of Averages," and in the list below, which specifies the material we have to discuss. The second series of numbers is very important, and in the *List* is placed in a parenthesis before each specimen; these are the *Museum numbers of the specimens*, and in my " Table " a separate column will be awarded them, as *they designate the specimens I have chosen, from which the averages are computed.*

From the *List* then, I find we can obtain our averages from the crania of the following North American Indians, viz.:—

4. *Indians from Peel's River.*—The collection contains two crania, both from Fort M'Pherson, Wyoming Territory, and both used in the " Table of Averages " (Mus. Nos. 323, 324).

5. *Newittee Indians.*—Five specimens make up the collection for these Indians, and all were obtained from Vancouver Island (Mus. Nos. 762–766 inclusive).

6. *Chemakum Indians.*—One calvarium in the collection from Port Townsend, W. T. (Mus. No. 241).

7. *Spokane Indians.*—A single cranium in the collection, from near Benton City, Montana (Mus. No. 129).

8. *Flathead Indians.*—The collection contained fifteen (perfect or imperfect) skulls, representing both sexes. There was also a mummified pappoose, and the " cast of the head of a Flathead Indian adult." These specimens were principally collected in Washington Territory, and averages can be obtained from four male skulls (Mus. Nos. 1614, 1930, 931, and 1934) and from two female skulls (Mus. Nos. 118, 1933).

9. *Clallam Indians.*—The collection contains only one skull, that of a boy ten years old. Although an average cannot be obtained from a single skull, yet in the absence of further material I have recorded the character of that skull, both in this and other instances where only one skull of any tribe was in the collection.

10. *Salish Indians.*—These are represented by the calvarium of a female child, 10 years old, and the cranium of an old man of 65 years of age. Both are entered in the table (Mus. Nos. 66 and 69).

11. *Chehalis Indians.*—A cranium, age and sex unknown, the calvarium of an aged female, and the calvarium of a male said to be 65 years old. The two latter I have entered in the Table (Mus. Nos. 694 and 695).

12. *Makah Indians.*—Four crania and a calvarium are recorded in the *List.* I present the average data of two male skulls, and simply enter the female specimen (Mus. Nos. 215, 333, *m.*; 247, *f.*).

13. *Nisqually Indians.*—The collection contains three crania and four calvaria. They were all obtained in Washington Territory, and I have utilised five, as shown in the Table (Mus. Nos. 213, 223, 548, *m.*; 224, 233, *f.*).

14. *Nez Perces.*—These celebrated Indians are only represented by three crania, the data for only two of which I have introduced (Mus. Nos. 700, 2032).

15. *Watlala Indians.*—The collection contains the calvarium of a male aged 35, of another aged 40, the data for both of which I have entered in the Table (Mus. Nos. 226, 227).

16. *Chinook Indians.*—The collection exhibits twenty-three nearly perfect skulls, and from these I have chosen five males and six females for our data in the "Table of Averages." They were nearly all collected in the region about the mouth of the Columbia River, Washington Territory. It is interesting to note that in the skulls of these Indians the average of the facial angles of the five male skulls is four degrees less than that of the six female skulls; further, the cranial capacity is less in the males than in the females (Mus. Nos. 214, 216, 217, 222, 232, *m.*; 70, 211, 212, 219, 221, 235, *f.*).

17. *Oregon Indians.*—Fourteen more or less perfect specimens of the skulls of these Indians are in the collection, and from these I have been enabled to obtain averages for three of each sex (Mus. Nos. 89, 1642, 1737, *m.*; 265, 1023, 1685, *f.*).

18. *Modoc Indians.*—Considerable difficulty has been experienced in procuring specimens of the skulls of some of our Indians, and these stand among the number. Of the seven crania in the collection I have obtained averages from four male skulls and one female (Mus. Nos. 6287, 1018, 1020, 1021, *m.*; 995, *f.*).

19. *Shoshone Indians.*—Two skulls from males of nearly the same age occur in the collection, and the averages from them are given in the Table (Mus. Nos. 179, 180).

20. *Snake Indians.*—Some half a dozen skulls from these Indians are in the museum; they have been gathered by different collectors in Idaho Territory. Data have been obtained from one male skull and from four female skulls, and the results are recorded in the Table (Mus. Nos. 688, *m.*; 686, 687, 689, 690, *f.*).

21. *Cascade Indians.*—One skull alone from a male 55 years of age represents this tribe. It was collected at Memalut Island, Columbia River, and the usual data from it are given in our Table (Mus. No. 696).

22. *Utah Indians.*—Four male skulls collected at Round Valley, California, represent this tribe, and although the zygomatic diameter is but given in Mus. No. 810, the entire series were utilised in the Table (Mus. Nos. 810, 811, 1566, 1567, *m.*).

23. *Ocki Pah Ute Indians.*—Mr Stephen Powers obtained at Walker Lake, Nevada, both a perfect and an imperfect skull of this tribe of Indians, which eventually came into the museum; the data from the perfect one alone is, however, recorded in our Table (Mus. No. 1547).

24. *Pah Ute Indians.*—We find quite an extensive collection of these, although many of the twenty-three specimens are imperfect, and we have been able to use but eleven of them. They are usually considered rather an intelligent though warlike tribe (Mus. Nos. 963, 697, 966, 971, 972, 1128, 1268, 1953, *m.*; 964, 970, 1794, *f.*).

25. *Utah Indians.*—There is a mummified head of an adult male in the collection, but besides this we find only the skulls of two children, which, for the sake of comparison, I have entered in the Table (Mus. Nos. 914, 915, ages 6 and 8 years).

26. *California Indians.*—Here we meet with a magnificent collec-

Table of Measurements from Skulls of California Indians (individual specimens), 11 Males and 11 Females, used in the " Table of Averages" :—

Mus. Nos.	Age.	Sex.	Cran. cap c.c.	C.	F. a.	L.	H.	Z. d.	B.
				Males.					
1131	40	M.	1160	486	77°	170	128	128	133
1303	40	M.	1150	492	76°	172	127	132	138
1326	40	M.	1385	529	70°	186	139	134	142
1341	40	M.	1225	486	76°	172	131	132	131
1439	40	M.	1220	493	67°	171	134	139	140
1637	40	M.	1470	516	68°	179	134	133	145
1651	40	M.	1220	499	69°	174	131	129	138
1682	40	M.	1490	522	69°	177	136	144	147
1721	40	M.	1350	503	73°	175	135	140	138
1726	40	M.	1300	508	75°	176	129	132	141
6598	40	M.	1310	506	75°	180	135	138	137
				Females.					
802	40	F.	1190	502	75°	186	127	131	128
1067	40	F.	1205	488	74°	172	127	125	136
1289	40	F.	1075	472	74°	167	119	119	131
1299	40	F.	1186	495	75°	179	128	128	135
1308	40	F.	1200	485	75°	170	129	129	138
1346	40	F.	1140	487	73°	173 ·	127	122	135
1355	40	F.	1240	498	78°	174	129	126	141
1364	40	F.	1220	502	74°	176	129	132	140
1366	40	F.	1090	480	73°	170	126	130	132
1374	40	F.	1240	487	73°	169	133	141	136
1386	40	F.	1225	489	77°	173	129	126	133

tion, probably one of the finest of the kind in existence, of four hundred and forty-four skulls, the majority of which are more or less perfect, both sexes and those from children of all ages being represented. The principal collectors of this vast array of valuable Indian crania from California in the Army Medical Museum have been Mr W. H. Dall, Mr Paul Schumacher, Rev. Stephen Bowers, and the parties connected with the United States Geographical Survey west of the 100th meridian in the year 1875. So large, indeed, is this collection in the Otis *List*, that the series has admitted of my selecting from it eleven skulls that belonged to males of 40 years of age each, and from, as near as possible, the same clan; in the same way eleven females were selected, being from the same clan as the males, and also each of 40 years of age. And as the averages from these twenty-two skulls will be much enhanced by having the individual data before us, I have presented that also in the preceding Table, in which, as in the "Table of Averages," the metric system is the one used. As the data obtained from such a long series are exceedingly valuable, I will in the sequel briefly point out some of the salient features of the comparisons made.

27. *Nevada Indians.*—Although the collection contains six crania and a calvarium of these Indians, they are for the most part so imperfect, that I found but two of them could be utilised in the "Table of Averages," and these were from males aged 50 and 55 years respectively (Mus. Nos. 1654, 1736).

28. *Aztec Indians.*—With the exception of a perfect female cranium, and that of a male, the age of the owner of which was not ascertained, fragmentary specimens alone represent the craniology of this interesting tribe of Indians. Data from the two perfect specimens are entered in the Table. Most of these specimens were collected in Arizona (Mus. Nos. 1845, 1999).

29. *Wintoon Indians.*—The collection contains only the calvarium of a female of 40 years of age, the data from which I have recorded in the Table. The specimen was collected at Weaverville, Cal. (Mus. No. 1548).

30. *Digger Indians.*—Here again we find but one specimen, that of a female 35 years of age, collected in California (Mus. No. 339).

31. *Cowcow Indians.*—Five crania of this tribe were obtained on their reservation at Round Valley, California; and from these I have obtained averages from two males and two females (Mus. Nos. 808, 812, *m.*; 807, 809, *f.*).

32. *Navajo Indians.*—As stated at the commencement of this article, the present writer has published in a previous number of this *Journal* the average data from eight skulls of Indians of this tribe, taken from the *List;* and I now choose the data from the crania of four females for our table to compare with these, the eight alluded to being males. The collection at the Army Medical Museum has in it twenty-two skulls of this tribe, in a more or less perfect condition (Mus. Nos. 788, 97, 130, 134, 633, 784, 785, 1086, *m.*; 131, 177, 786, and 787, *f.*).

33. *Apache Indians.*—In another issue of this *Journal* I published

the average data of eleven skulls of this tribe, but three of these specimens were in my private collection, and have since been placed in the anatomical collections of the University of Edinburgh. They, too, were all males. I simply reproduce the data in our Table, together with the additional measurements taken from the crania of seven Apache squaws in the Army Medical Museum. Thirty-five Apache skulls are reported in the Otis *List*, and a very fair proportion of them are in excellent condition (Mus. Nos. 1530, 135, 209, 357, 370, 889, 890, 1168, and the three in the Edinburgh Museum, *m.*; 1473, 132, 634, 887, 891, 909, 1276, *f.*).

34. *Hare Indians.*—The collection possesses only one cranium, that of a male 35 years of age, obtained at Fort Good Hope, Mackenzie River, by Mr R. Kennicott. It has been duly entered in our Table (Mus. No. 328).

35. *Blackfeet Indians.*—There were five skulls in hand in 1880, representing these Indians, but four of these were imperfect, and I have recorded in the table the data taken from one female calvarium only. This specimen was obtained at Fort Union, New Mexico, by Dr F. V. Hayden (Mus. No. 328).

36. *Piegan Indians.*—From the fourteen specimens in the collection we have been enabled to select four males and five females for our present purposes, all being crania with their data complete (Mus. Nos. 128, 869, 870, 1994, *m.*; 871, 872, 1996, 1997, *f.*).

37. *Gros-Ventre Indians.*—Of the four specimens but one is sufficiently perfect for our purpose, and that a calvarium of a male 25 years of age (Mus. No. 383), obtained from a graveyard of this tribe on the Upper Missouri River by Mr T. A. Culbertson.

38. *Mandan Indians.*—Three calvaria, a male and two females, in the collection have been utilised in the Table. They all came from Fort Berthold, D. T. (Mus. Nos. 316, *m.*; 136, 317, *f.*).

39. *Arickaree Indians.*—A single calvarium from a male 45 years of age was collected in the same locality where the Mandan skulls were obtained (Mus. No. 137).

40. *Assiniboine Indians.*—Five crania, more or less imperfect, are in the collection, so that only a single male skull and two female skulls could be utilised in the Table (Mus. Nos. 159, *m.*; 160, 1264, *f.*).

41. *Sioux Indians.*—This is a large, warlike, and powerful tribe of Indians; and for the most part the men are tall, and of a fine physique. Thirty skulls are in the museum. From these I have selected for our table thirteen male skulls and five females, ranging between 20 and 60 years of age (Mus. Nos. 13, 330, 483, 665, 792, 793, 816, 1029, 1119, 1155, 1157, 1616, *m.*; 2046, 315, 781, 896, 2047, *f.*). Among the collectors of skulls of these more northern tribes of Indians we note names so familiar to science as those of Dr Elliot Coues, Professor J. S. Newberry, Professor Joseph Henry, and others.

42. *Brule Sioux Indians.*—Numerous skeletons and crania from this tribe of the Sioux nation are in the museum (twenty-four specimens). The skulls are in such an excellent state of preservation that I have

been enabled to select eleven males and ten females. Nearly all of these were obtained at Camp Sheridan, Nebraska, a military station within the confines of the country over which this tribe of Indians range (Mus. Nos. 1852, 1895, 1896, 1898, 1899, 1901, 1905, 1910, 1912, 1913, 1916, *m.* ; 1897, 1900, 496, 501, 502, 1903, 1904, 1906, 1908, and 1911, *f.*).

43. *Ogallalla Sioux Indians.*—Of these the museum possesses four skeletons, ten crania, and a mummified pappoose, a very valuable assortment, and they have admitted of our choosing for the Table four male and five female crania from which to compute the cranial averages for the tribe (Mus. Nos. 199, 482, 1914, 1915, *m.* ; 1853, 1854, 200, 481, and 2034, *f.*).

44. *Yankton Sioux Indians.*—Thirteen crania and a skeleton illustrate the osteology of this tribe, and from these I have chosen six crania from each sex, from which the average dimensions have been computed for our Table (Mus. Nos. 332, 497, 500, 636, 1789, 926, *m.* ; 358, 493, 494, 495, 499, and 642, *f.*).

45. *Sissiton Sioux Indians.*—This tribe of the Sioux nation is represented in the museum by three skeletons and thirteen crania, from which I have been able to select six males and four females (Mus. Nos. 1791, 1792, 1795, 1799, 1920, 2039, *m.* ; 1790, 944, 1797, and 1923, *f.*).

46. *Santee Sioux Indians.*—Only one cranium is in the collection, and that from a female of 50 years of age (Mus. No. 492).

47. *Teton Sioux.*—But a single calvarium is in the collection, from a male of 50 years of age, which was procured at Fort Peck, Montana Territory (Mus. No. 1793).

48. *Wahpeton Sioux.*—Three crania are in the museum, and I have taken the average data from two males for our table (Mus. Nos. 1919, 1991, *m.*).

49. *Menominee Indians.*—Professor Joseph Henry presented the museum with an imperfect cranium belonging to this tribe of Wisconsin Indians, which is the only specimen in the collection. The data, though incomplete, are given in the Table·(Mus. No. 77).

50. *Dakota Indians.*—A skeleton, and fourteen more or less perfect skulls, represent the osteology of this important tribe of Indians, and from these eight males and four females have been selected for the "Table of Averages" (Mus. Nos. 945, 300, 301, 305, 306, 307, 371, 1015, *m.* ; 302, 303, 304, 371, *f.*).

51. *Ponka Indians.*—Thirty-two crania, representing both sexes and all ages, are in the museum, and as fully two-thirds are in a perfect condition, I have· secured data from fourteen male crania, with an average age of something over 41 years, and from ten crania of Ponka squaws, of the same average age as the males. Most of these specimens came from the Ponka agency at Niobrara River, Dakota Territory (Mus. Nos. 486, 487, 490, 794, 795, 831, 833, 834, 835, 836, 837, 877, 880, 882, *m.* ; 484, 485, 488, 489, 796, 797, 798, 875, 881, and 883, *f.*).

52. *Crow Indians.*—The cranium of an adult male and female, data from both of which are in the Table (Mus. Nos. 173 and 884).

53. *Caddo Indians.*—Three perfect calvaria from adult males are in the museum, aged respectively 35, 45, and 50 years of age (Mus. Nos. 517, 518, and 519).

54. *Minnetaree Indians.*—Although the collection representing this tribe is large, but few of the specimens are so perfect as to be utilised in our Table. The twenty-five skulls were collected by Dr F. V. Hayden and Lieutenant G. K. Warren, U.S. Corps of Engineers (Mus. Nos. 359, 372, 373, *m.* ; 84 and 375, *f.*).

55. *Winnebago Indians.*—Only three specimens, two perfect male crania and one a squaw, aged 45 years, are all that can be utilised (Mus. Nos. 360, 491, *m.* ; 346, *f.*).

56. *Pawnee Indians.*—Seven male crania and the skeleton of an old female make up the collection of this tribe, and my averages have been computed from five male crania and from the female skull (Mus. Nos. 529, 530, 531, 550, 912, *m.* ; 778, *f.*).

57. *Kickapoo Indians.*—A single male cranium and one female, aged 30 and 65 years respectively; they have been entered in the Table for comparison (Mus. Nos. 1170, *m.* ; 1002, *f.*).

58. *Arapahoe Indians.*—The full skeleton of "Walk-a-bed," a medicine man of this tribe, is in the collection, and with it eleven crania of other individuals, all males but one (Mus. Nos. 6499, 12, 667, 669, 774, 892, and 1832, *m.*).

59. *Cheyenne Indians.*—Twenty-three skulls and two complete skeletons of this powerful and warlike tribe have, through the intervention of collectors, well supplied the museum with craniological material. The averages are computed from seventeen males, but I have been able to select only one female skull sufficiently complete to compare with these in the Table. The cranium with museum number 6525 belonged to the Cheyenne chief "Cunning Jim," who was killed in a fight with U.S. troops (Mus. Nos. 2036, 8, 9, 146, 149, 150, 157, 464, 526, 528, 668, 715, 773, 913, 1762, 6525, 1235, *m.* ; 10, *f.*).

60. *Kaw Indians.*—Five perfect crania represent this tribe in the collection, all of which I have been able to utilise in the Table (Mus. Nos. 152, 158, 520, *m.* ; 151, 153, *f.*).

61. *Shawnee Indians.*—Of these we find only a calvarium of a male 50 years of age (Mus. No. 1007).

62. *Pottawatomie Indians.*—Up to 1880 the museum had received but three skulls from members of this tribe. Two were collected by Mr E. L. Berthoud, and the other by Mr P. R. Hoy; I have utilised the data given for all of them (Mus. Nos. 355, 549, *m.* ; 349, *f.*).

63. *Osage Indians.*—This well-known tribe is represented by only four perfect and one imperfect skull (Mus. Nos. 343, 414, 509, 510, *m.*; 413, *f.*)

64. *Seneca Indians.*—One good cranium from a male, 50 years of age, alone represents this tribe in the collection (Mus. No. 522).

65. *Wishitaw Indians.*—Surgeon Blancoe E. Fryer, U.S. army, an officer whose contributions to the collection of human crania in the museum have been so extensive that it may almost be said that he was one of its founders, presented the entire series of the ten skulls

of the present tribe. Nine of them have been found available for use in the present connection (Mus. Nos. 155, 511, 512, 513, 514, 515, 516, 910, 911, *m.*; 525, *f.*).

66. *Kiowa Indians.*—Five skulls were in the museum in 1880, and of these we can obtain averages from two males and one female (Mus. Nos. 772, 1003, *m.*; 771, *f.*)

67. *Choctaw Indians.*—All are females, there being two complete skeletons and three crania. Data have been obtained from four crania (Mus. Nos. 621, 622, 623, 717, *f.*).

68. *Chickasaw Indians.*—The museum has but one imperfect skull from this tribe, that of a male of 40 years of age (Mus. No. 309).

69. *Iowaulkeno Indians.*—Here again is only one specimen to represent a tribe (Mus. No. 69, *m.*).

70. *Kechi Indians.*—There are only three crania in the museum, and data are obtained from a male and female skull (Mus. Nos. 523 and 524, *m.* and *f.*).

71. *New Mexican Indians.*—From the seven crania tabulated in the *List*, I succeeded in selecting four, from which the averages in the Table were computed (Mus. Nos. 133, 351, 1172, 1173, *m.*).

72. *Comanche Indians.*—Eight crania and a perfect skeleton of this Texan tribe of Indians are in the museum, and three male crania and one female gave me the required data. The cranium numbered 6563 belonged to " Eath-Ath Qua-ha " (Red day), a Comanche chief who was killed near Fort Richardson, Texas (Mus. Nos. 345, 1559, 6563, *m.*; 1000, *f.*).

73. *Lipan Indians.*—The museum possesses three crania, two of which furnish the desired data (Mus. Nos. 266, 553, *m.*).

74. *Tonkaway Indians.*—Six very excellent crania of this tribe are in the museum, and so perfect are they that five could be utilised in the present connection (Mus. Nos. 319, 321, 322, 1004, 5528, *m.*).

75. *Texan Indians.*—Two of the four specimens in the collection were sufficiently perfect to use, and their averages are given in the Table (Mus. Nos. 313, 551, *m.*).

76. *Pueblo Indians.*—Two imperfect skulls of children, and three others of adults, make up this series; but only one specimen, a male 55 years of age (Mus. No. 682), was of any service.

77. *Mexican Indians.*—Neither the tribes of the present group nor of the last-mentioned are designated, and as there are a number of different tribes of both Pueblo and Mexican Indians, this fact rather detracts from the value of the data in these two instances; at the same time I have entered them in the Table for what they may be worth (Mus. Nos. 28, 273, 5124, *m.*; 721, *f.*).

78. *Cree Indians.*—An imperfect cranium from a male of 50 years of age represents this tribe (Mus. No. 1271, *m.*).

79. *Chippewa Indians.*—Although a considerable amount of material has been collected illustrative of the craniology of this tribe (twenty specimens), the greater portion is found to be quite imperfect, so much so indeed that but three of the crania of males furnished the required data for comparison, and only one female skull. The skeleton of a Chippewa dwarf, from a female of 85 years

of age, with a hydrocephalic cranium, has a height of 1081 mm., a cranial capacity of 2760 c.c., and a facial angle of 103 degrees (Mus. Nos. 187, 327, 1255, *m.*; 380, *f.*).

80. *Wisconsin Indians.*—Eight crania, including two desirable ones for our present purpose, make up the collection for this tribe (Mus. Nos. 826, 828, *m.*).

81. *Sac Indians.*—A single calvarium represents the Sacs, that of a male of 65 years of age. Its measurements are given in the Table (Mus. No. 1009).

82. *Pequod Indians.*—This tribe is but meagrely represented, for there is only an imperfect skull of a male aged 45 from which to obtain data (Mus. No. 398).

83. *Miami Indians.*—Of these there is but an imperfect calvarium of a female of 65 years of age, the several measurements from which have been duly entered in the Table (Mus. No. 1005).

84. *Seminole Indians.*—Through the donations of various collectors, this celebrated tribe has furnished the museum with the crania of five individuals; one of these is from the famous Seminole chief, Chi-Ki-Kee, who was killed in the Everglades in 1846 (No. 6184). All the specimens are from Florida, but only two are sufficiently perfect to secure the necessary measurements (Mus. Nos. 6184, *m.*; 335, *f.*).

This completes our category of material in so far as the eighty-four tribes of North American Indians in the *List* of the Army Medical Museum of 1880 is concerned. It is followed in that work by similar descriptions of about sixty crania of " Unknown Indians," but upon carefully looking these over I find nothing of sufficient importance to warrant special notice here, or of a nature that would assist us in the present connection.

[TABLE OF AVERAGES.

TABLE OF AVERAGES.

(Data given in the Metric System.)

No. & Tribe	No.	Age	Sex								Remarks
16. Chinook Indians	5	46	M.	1295	489	66°+	158+	127+	*188	151	*Z.d. not obtained in Mus. No. 217, and due allowance made.
17. Oregon Indians	6	36+	F.	1302+	481+	70°	155+	126+	188	149+	Maximum age, 40 } F. Minimum age, 25 } In Mus. No. 89, F. spec. the Z.d. was not known.
	3	56+	M.	1268+	499+	71°+	170+	132+	185	145+	
18. Modoc Indians	3	41+	F.	1123+	476+	71°+	165	127+	126+	134	
	4	41+	M.	1383+	502+	69°+	168+	138+	140+	148+	
19. Shoshone Indians	1	45	F.	1320	498	68°	165	124	135	146	From Idaho Territory.
20. Snake Indians	2	87+	M.	1385	497	72°+	176	124	134	139	
21. Cascade Indians	1	50	M.	1230	492	72°	173	128	140	138	
	4	50	F.	1225	502+	76°+	172+	125+	133	141	
	1	55	M.	1340	514	68°	165	121	148	154	From Memalut Island; Columbia River.
22. Ukah Indians	4	53+	M.	1236+	503+	73°	180+	130	132	180+	Age in Mus. No. 810 unknown, and the average of only 3 used.
23. Ocki Pah Ute Indians	1	50	M.	1240	508	76°	178	186	140	185	From Walker Lake, Nevada.
24. Pah Ute Indians	8	41+	M.	1329+	504+	78°	177+	129+	188+	187+	Maximum age, 50; 3 of 40, 2 of 50. Minimum age, 25.
25. Utah Indians	3	38+	F.	1387+	505+	78°+	174	126	131+	139+	No adult skulls in the collection; and these two children only given as a matter of interest, and not for comparison with the rest of the Table. Their sexes were not known.
	1	8	?	1055	459	79°	163	117	108	126	
	1	6	?	945	440	80°	154	109	98	125	

Tribes of North American Indians.	The Number of Specimens used in obtaining the Averages.	Age.	Sex.	Cran. cap. (cc.)	C. (mm.)	F. a.	L. (mm.)	H. (mm.)	Z. d. (mm.)	B. (mm.)	Remarks.
26. California Indians,	11	40	M.	1298+	503+	72°+	176+	132+	184+	139+	From this large collection 11 males of 40 years of age each, with full data, could be selected, and the same for the females.
	11	40	F.	1179+	489+	74°+	173+	127+	128+	135	
27. Nevada Indians,	2	52+	M.	1225	494	68°+	173+	136+	182	182+	
	1	?	M.	1410	484	76°	161	143	129	141	
28. Aztec Indians,	1	75	F.	1220	460	72°	150	138	125	189	
29. Wintoon Indians,	1	40	F.	1115	486	78°	173	121	131	130	From Weaverville, California.
30. Digger Indians,	1	85	F.	1375	405	76°	169	135	136	141	From California.
31. Cowcow Indians,	2	42+	M.	1130	491	74°+	177	121+	129	132+	From Round Valley Reservation, California.
	2	87+	F.	1222+	483	74°+	170	128+	125	136	
32. Navajo Indians,	8	89+	M.	1419+	508+	77°+	175+	137	184+	140+	
	4	51+	F.	1312+	493	78°+	166+	132+	131+	140+	
33. Apache Indians,	11	86+	M.	1410+	506+	77°+	171+	138+	135+	145+	
	7	85	F.	1285+	477+	78°+	168+	123+	129	139+	
34. Hare Indians,	1	85	M.	1620	517	71°	178	135	144	149	
35. Blackfeet Indians,	1	80	F.	1250	502	72°	175	129	132	138	
36. Piegan Indians,	4	55	M.	1416+	511+	78°+	182+	134+	141	189+	
	5	48	F.	1309+	497	74°+	174	129+	132+	139+	
37. Gros Ventre Indians,	1	25	M.	1610	517	71°	184	140	130	144	
	1	18	F.	1370	489	80°	176	125	114	186	
38. Mandan Indians,	2	57+	M.	1442+	520	72°	187+	134+	144+	144+	
39. Arickaree Indians,	1	45	F.	1440	517	68°	186	138	138	141	
40. Assiniboine Indians,	1	70	M.	1310	508	77°	179	122	132	143	
	2	80	F.	1280	507+	75°	181	129+	133	140	

Notes (from column annotations):

- In the *List* the measurement for "B" has been omitted for Mus. No. 1858 (F.), so the average is for only 4 in that special case.
- The Z.d. lacking in one specimen (Mus. No. 872).
- In Mus. No. 158 H. was unknown, and in No. 520 Z.d. was unknown.

No.	Tribe	n	Sex								
41.	Sioux Indians	13	M.	48+	1460	520	72°+	181+	182+	142+	145+
		5	F.	35	1273	490+	74°+	172+	126	128+	144
42.	Brule Sioux Indians	11	M.	46+	1455+	518+	70°+	182+	182+	140+	143
		10	F.	48	1369+	505+	70°+	177+	127+	140+	141+
43.	Ogallalla Sioux Indians	4	M.	51+	1420	513	71°	179+	130+	147	144+
		5	F.	47	1354	504+	72°+	176+	131+	136+	140
44.	Yonkton Sioux Indians	6	M.	41+	1410+	511+	70°+	177+	134	140+	140+
		6	F.	39+	1315	501+	73°	175	127+	134+	135+
45.	Sissiton Sioux Indians	6	M.	35+	1373+	509+	71°+	179+	183+	187+	139+
		4	F.	50	1312+	507+	78°	178+	132+	138	139+
46.	Santee Sioux Indians	1	M.	50	1220	496	79°	176	128	138	137
47.	Teton Sioux Indians	1	F.	50	1320	514	73°	173	138	145	145
48.	Wahpeton Sioux	2	M.	24	1560	516+	78°	182+	135	128	144+
49.	Menominee Sioux	1	F.	15	1490	479	83°	162	?	?	146
50.	Dakota Indians	8	M.	48+	1540+	528+	74°+	186+	135+	145	146+
		4	F.	41+	1415	510+	75°+	180	127+	135	143+
51.	Ponka Indians	14	M.	41+	1439+	508	73°	177	131+	140	144+
		10	F.	41+	1314+	495+	74°+	174+	129+	129+	140+
52.	Crow Indians	1	M.	45	1220	492	74°	176	124	129	135
		1	F.	50	1280	509	75°	177	137	137	140
53.	Caddo Indians	8	M.	43+	1238+	490	77°	166	126+	132	144+
		9	F.	50	1376+	512	75°+	186+	132+	139	138+
54.	Minnetaree Indians	1	M.	60	1450	518	74°+	183	138	140	143
		2	F.	62+	1427+	513	74°+	171	128+	145	147+
55.	Winnebago Indians	1	M.	45	1255	495	82°+	178	130	130	186
		5	F.	27	1425	507+	72°	180+	134+	138+	144
56.	Pawnee Indians	1	M.	60	1170	482	74°+	167	120	133	140
		1	F.	30	1400	507	74°	173	144	144	142
57.	Kickapoo Indians	1	M.	65	1330	497	78°	177	136	137	140
		6	F.	40+	1400	509	73°	179+	184+	141	141+
58.	Arapahoe Indians	17	M.	55+	1439+	511+	74°+	179+	136+	143+	143
		1	F.	20	1290	489	79°	173	129	127	138
59.	Cheyenne Indians	8	M.	50	1401+	506+	71°+	176+	140	137+	143
		2	F.	52+	1302+	487+	70°+	166	129+	133+	143
60. / 61.	Kaw Indians / Shawnee Indians	1	M.	50	1450	507	77°+	178	188	141	140

Tribes of North American Indians.	The Number of Specimens used in obtaining the Averages.	Age.	Sex.	Cran. cap.	C.	F.a.	L.	H.	Z.d.	B.	Remarks.
				c.c.	mm.		mm.	mm.	mm.	mm.	
62. Pottawatomie Indians,	2	47+	M.	1612+	532	74°	182	136	149	156	In Mus. No. 355 Z.d. was unknown, and in No. 549 F.a. was unknown.
	1	70	F.	1280	495	75°	175	127	?	137	
63. Osage Indians,	4	42+	M.	1368+	488+	74°+	173+	133+	182	141+	
	1	35	F.	1250	476	75°	162	130	188	140	
64. Seneca Indians,	1	50	M.	1525	527	72°	176	140	148	154	
65. Wishitaw Indians,	8	40	M.	1266+	491+	74°+	169+	132+	188	142+	
	1	50	F.	1260	478	73°	157	124	129	144	
66. Kiowa Indians,	2	52+	M.	1517+	523+	74°+	180	137	136	148	
	1	22	F.	1290	488	73°	170	128	180	135	
67. Choctaw Indians,	4	45	F.	1419+	480+	77°+	167	185+	125+	189+	
68. Chickasaw Indians,	1	40	M.	1520	527	81°	190	186	?	136	
69. Jowonikeno Indians,	1	35	M.	1360	495	71°	167	183	145	148	
70. Kechi Indians,	1	40	M.	1225	476	74°	162	127	129	141	
71. New Mexican Indians,	4	55	M.	1430	510	77°	179	139+	129+	137+	Z.d. in Mus. No. 1172 was not known, and due account made for it in consequence.
72. Comanche Indians,	3	55	M.	1338+	505	72°+	176+	131+	140+	139+	
	1	35	F.	1483	488	75°	170	123	131	133	
73.	2	32+	M.	1427+	507+	76°+	178	131+	187	146	
74.	5	42	M.	1297	466+	74°+	169+	181+	133+	141+	
75.	2	40	M.	1457+	521	76°+	183+	137+	133+	188	
76.	1	55	M.	1160	476	78°	169	130	?	188	
77. Mexican Indians,	3	40	M.	1456+	509+	75°+	181	136	131+	141	
	1	45	F.	1220	485	79°	164	121	124	145	
78. Cree Indians,	1	50	M.	1455	534	80°	192	131	?	186	
79. Chippewa Indians,	3	46+	M.	1413+	501	74°+	188	131+	141+	148+	The Z.d. in Mus. No. 828 only was given and used.
	1	50	F.	1110	476	70°+	184	182	152	140	
80. Wisconsin Indians,	2	87+	M.	1305	500+	76°+	177+	134	125	133+	
	1	65	M.	1410	514	76°	185	130	137	142	
81. Sac Indians,	1	45	M.	—	521	?	186	?	?	140	
82. Pequod Indians,	1	65	F.	1200	495	78°	176	180	?	137	
83. Miami Indians,	1	80	M.	1550	552	76°	199	148	149	148	
84. Seminole Indians,	1	80	F.	1530	553	80°	190	132	132	143	

Analytical Summary and Concluding Remarks.

As has already been stated, this paper, with its "Table of Averages," takes into consideration the entire collection of Indian crania, representing eighty-four tribes, that were in the United States Army Medical Museum in 1880. In its compilation, the chief difficulty I have had to deal with has been the lack of a proper system of tabulation in the published List; the data being presented in paragraphs, and not in columns, as they should be.

In choosing the skulls enumerated in the List from which to compute the average data for the Table, the most perfect specimens were selected in each instance, both in the case of those belonging to male and female individuals, and always in the greatest possible number, the skulls of children having intentionally not been taken into consideration. It has been my constant aim to select those of as near as possible the same age, and I believe in no instance has a skull been chosen that came from an individual under eighteen years of age, and rarely where the person exceeded seventy. My satisfaction has been most complete when I have found that the List offered a goodly number of crania of Indians who were about forty years of age, and it will be observed that in the case of the California Indians it actually admitted of selecting eleven crania from either sex wherein the age of each individual Indian was exactly forty years.

In many instances where a tribe was represented by one cranium only I have invariably entered the measurements in the Table, for the reasons already stated in a preceding paragraph. It will be observed that in so far as averages are strictly concerned, the series range all the way from two specimens to seventeen, which latter occurred in the case of the crania of the male Cheyenne Indians (No. 59).

Speaking now with exactness, we find, where averages have been taken from two or more skulls, that in the matter of "age" the Table will show that the lowest average age recorded is *twenty-four years*, and the highest *eighty years*.

Upon glancing down the column headed "Sex," it will be

further noted that data have been secured very nearly as often from a series of crania of squaws, as from the " bucks," of any particular tribe ; this fact, I think, more than doubles any value that may attach to these Tables.

Dealing next only with those crania from which I obtained data for the above Tables, I find, so far as all the *individual* specimens which were utilised are concerned, the following facts as to the *Cranial Capacity*.

Greatest cranial capacity in any single male cranium was in No. 549, a Pottawatomie Indian, 1785 c.c.; and in a female a Brule Sioux squaw (No. 1904), 1590 c.c. Least cranial capacity in any single male cranium was in No. 548, a Nisqually Indian, 1080 c.c.; and in a female, an Oregon squaw (No. 1685), 1060 c.c.

Next as to the average cranial capacity. Greatest average cranial capacity for males was in the Pottawatomie Indians (No. 62 of the Table), 1612 c.c.; and for females, in the Mandan Indians (No. 38 of the Table), 1442 c.c. Least average cranial capacity for males was in the Cowcow Indians (No. 31 of the Table), 1130 c.c.; and for females, in the Oregon Indians (No. 17 of the Table), 1123 c.c. The column in the Table devoted to the cranial capacities shows, however, that in several instances, as in the Pah Utes (No. 24), the average cranial capacity of the females is greater than that of the males, which is a fact of high importance.

Briefly to formulate our first deduction, then, we find—

(1) *That, taking these eighty-four tribes of North American Indians into consideration, the average cranial capacity of the males is greater than the average cranial capacity of the females, and that the females show a lower cranial capacity than is attained by the males. This law applies with equal truth to the individual; but on the other hand, we find that in certain tribes the average cranial capacity of the females may be greater than that of the males of the same tribe.*

Of all the specimens chosen from the *List* for use in the present connection, I find with respect to the *Circumference,* the following facts, viz. :—

Greatest circumference in any single male cranium was in

No. 549, a Pottawatomie Indian, 556 mm.; and in the female was in a Seminole squaw (No. 335), 533 mm. Least circumference in any male cranium was in No. 764, a Newittee Indian, 465 mm.; and in a female was in an Aztec squaw (No. 1999), 460 mm.

The average cranial circumference was as follows :—

Greatest average cranial circumference for males was in the Pottawatomie Indians (No. 62), 532 mm.; and for females was the Mandan Indians (No. 38), 520 mm. Least average cranial circumference for males was found to be in the Tonkaway Indians (No. 74), 466 mm.; and for females was in the Oregon Indians (No. 17), 476 mm.

From an inspection of the " Table of Averages," another fact seems to be evident with respect to the circumference of the cranium, that so far as these examinations carry us it would seem that for any particular tribe the average circumference of the male crania is always greater than the average circumference of the female crania.

To formulate our second deduction, then, we are to observe—

(2) *That in these eighty-four tribes of North American Indians, the average circumference of the cranium in the male is greater than in the female; on the other hand, the lowest average cranial circumference is attained by the males in one tribe. But when we come to compare the average cranial circumference for any particular tribe, it will always be found to be greater in the males than it is in the females. Again, as applied to the individual, the greatest cranial circumference was found to have been attained in a male Indian skull, while the skull with the least circumference is that of a female.*

Next, as to the *Facial Angle,* we find the following facts are brought to light as a result of my investigations, viz. :—

Greatest facial angle in any single male cranium was in No. 715, a Cheyenne Indian, 84 degrees; and in a female, a Dakota squaw (No. 314), 84 degrees. Least facial angle of any single male cranium was in No. 232, a Chinook Indian, 60 degrees; and in a female, a Nisqually squaw (No. 224), 64 degrees.

With respect to the average facial angle, as shown in the Table, we find the following, viz. :—

Greatest average facial angle for the crania of males was in the tribe of Wahpeton Sioux Indians (No. 48 of the Table), 78 degrees; and for females was in the Pah Ute Indians (No. 24 of the Table), 78 degrees. Least average facial angle for the crania of males was in the Watlala Indians (No. 15 of the Table), 62 degrees ; and for females was in the Flathead Indians (No. 8 of the Table), 66 degrees.

It will be found, however, that for the same tribe the average facial angle of the crania of the females may be greater than the average facial angle of the crania of the males. Instances of this may be seen in the Dakota and Ponka Indians (Nos. 50 and 51 of the Table).

Having these facts before us, we are in a position to formulate our third deduction, viz. :—

(3) *That in these eighty-four tribes of North American Indians, the average facial angle of the crania of the males is equal to the average facial angle of the crania of the females; and that the greatest angle attained by the face of a male cranium was equal to the greatest angle attained by the face of a female cranium. Further, the least average facial angle of the crania of the males was less than the least average facial angle of the crania of the females; and for the individual skulls, the one having the smallest facial angle of any came from a male. In the same tribe it may happen that the average facial angle of the crania of the females may be greater than the average facial angle of the crania of the males.*

As to the *Length* of the cranium in these North American Indians, we find the following facts, viz. :—Greatest length of any single male cranium was in No. 1015, a Dakota Indian, 202 mm.; and in a female, a Seminole squaw (No. 335), 190 mm. Least length of any single male cranium was in No. 69 a Salish Indian, 142 mm.; and in a female, a Chinook squaw (No. 211), 146 mm.

The average length of the crania in these Indians, as shown in the Table, was as follows:—Greatest average length of the cranium in males was shared in common by the Dakota and Minnetaree Indians (Nos. 50 and 54 of the Table), in

which tribes it is 186 mm.; and in females was in the Mandan Indians (No. 38 of the Table), 187 mm. Least average length of the cranium in males was in the Watlala Indians (No. 15 of the Table), 157 mm.; and in females is shared in common by the Flathead and Chinook Indians (Nos. 8 and 16 of the Table), 155 mm.

Another fact becomes evident to us, upon referring to the column containing this data in the "Table of Averages," viz., that for the same tribe the average length of the skull is greater in the males than in the females.

For our fourth deduction, then, we have the following statement to formulate, viz. :—

(4) *That in these eighty-four tribes of North American Indians, the average length of the cranium in the females is slightly greater than it is in the males, but the least average length of the cranium is somewhat greater in the males than it is in the females. Again, on the other hand, the longest skull and the shortest skull, both came from males, while in the same tribe the greatest average cranial length is always in the favour of the males.*

Passing next to the *Height*, we have the following facts, viz.:—Greatest height of any single male cranium was in No. 6184, a Seminole chief, 148 mm.; and in a female, an Ogallalla Sioux squaw (No. 1853), 143 mm. Least height of any single male cranium was in a Mojave Apache (No. 209), and in a female, an Apache squaw (No. 132), 108 mm.

Turning next to the average height of the cranium, as shown in the Table, we find the following:—Greatest average height of the cranium for males was in the Kaw Indians (No. 60 of the Table), in which tribe it is 140 mm.; and for females was in the Choctaw Indians (No. 67 of the Table), 135 mm. Least average height of the cranium for males was in the Watlala Indians (No. 15 of the Table), 120 mm.; and for females was in the Apache Indians (No. 33 of the Table), 123 mm.

It will be observed that in the same tribe the average height of the cranium may be either more or less in the males than in the females, a fact readily to be ascertained from the Tables.

Our fifth deduction then will be formulated as follows:—

(5) *That in these eighty-four tribes of North American Indians the average height of the cranium in the males is greater than it is in the females, but that the least average height was found to characterise a series of crania from males. And, upon comparing the average height of the cranium for the same tribe, the height of the skull may average either more or less in the males than it does in the females.*

The following may be said as to the *Zygomatic diameter :—* Greatest zygomatic diameter in any single male cranium was No. 2036, a Cheyenne Indian, 169 mm.; and in a female, a Brule Sioux squaw (No. 496 of the *List*), 173 mm. Least zygomatic diameter in males was in the Apache Indians (specimen No. 357 of the *List*), 109 mm.; and for females was in a California Indian squaw (No. 1289), 119 mm.

The following data have been obtained from the column devoted to the zygomatic diameters:—Greatest average zygomatic diameter for males was in common in the skulls of the Pottawatomie Indians, and the Indians from Peel's River (Nos. 62 and 64), 149 mm.; and in the females was in the Mandan Indians (No. 38 of the Table), 144 mm. Least average zygomatic diameter for males was in the Wahpeton Sioux Indians (No. 48 of the Table), 128 mm.; and for females was in the Mandan Indians (No. 8 of the Table), 124 mm.

Further, the average zygomatic diameter in the crania of the females is either equal to or less than it is in the males; in the crania of the males, however, this average diameter is generally greater than in the crania of the females.

To formulate our sixth deduction, then, we find—

(6) *That in these eighty-four tribes of North American Indians, the average zygomatic diameter of the crania of the males was greater than in the crania of the females, and the least average zygomatic diameter was found in a series of crania of females. Of the individual crania, however, the greatest zygomatic diameter was in the skull of a female, and the least one in the skull of a male. In the crania of the males the average zygomatic diameter was sometimes less than, sometimes equal to, although generally greater than, the average zygomatic diameter of the crania of the females.*

Finally, with reference to the *Breadth,* we have been

enabled to deduce the following facts from our investigation, viz.:—

Greatest breadth of any single male cranium was in No. 223, a Nisqually Indian, and in No. 1934, a Flathead Indian, in each of which it was 174 mm.; and in a female, a Nisqually squaw, No. 233 of the *List*, 161 mm. Least breadth of the male cranium was in No. 808 of the *List*, a Cowcow Indian, 127 mm.; and for females was in a California squaw (No. 802), 128 mm.

Turning to our Table for the average data, we are enabled to obtain the following, viz.:—

Greatest average breadth for males was shared in common by the skulls of the Flathead and Nisqually Indians (Nos. 8 and 13 of the Table), 164 mm.; and for females was in the Nisqually Indians (No. 8 of the Table), in which tribe it was 160 mm. Least average breadth for males in the Ukah Indians (No. 22 of the Table), 130 mm.; and for females, was in the Oregon Indians (No. 17 of the Table), 134 mm.

More than this, in the same tribe we find that the average breadth of the skull in males is sometimes greater than, sometimes equal to, and sometimes less than, it is in the females.

Formulating our seventh and last deduction, then, we may say:—

(7) *That in these eighty-four tribes of North American Indians, it would seem that the skull attained to a greater average breadth in the males than it did in the females, while the skull of the least average breadth was found to belong to a male; this holds good for the skulls of the individual as well, for both the broadest and the narrowest skulls came from males. Again, we are to observe that the average breadth of the skull in the females may be as much as it is in the males, or it may be less than, or even greater than, the average breadth of the skulls of the males.*

At the commencement of this memoir I made the statement that it was not my intention to figure any of the crania dealt with in its pages, indeed I have been so circumstanced that it would have been impossible for me to have done so even had I so planned; but now that it is completed I can see only too plainly the advantages which would have resulted from such illustration. More especially would it have been desirable to

have given reduced figures from photographs of those more typical skulls alluded to in these the concluding paragraphs; I refer to such specimens, for example, as the skull with the greatest cranial capacity, or with the greatest facial angle, or the greatest length or breadth, and so on. It is just possible that I may be enabled to accomplish this upon some future occasion.

CAN THE EXISTENCE OF A TENDENCY TO CHANGE IN THE FORM OF THE SKELETON OF THE PARENT RESULT IN THE ACTUALITY OF THAT CHANGE IN THE OFFSPRING?

By W. Arbuthnot Lane, M.S., F.R.C.S., *Senior Demonstrator of Anatomy, Guy's Hospital; Assistant-Surgeon to the Hospital for Sick Children.*

In a paper read recently before the Fellows of the Obstetrical Society, entitled " What are the Chief Factors that determine the Differences which exist in the form of the Male and Female Pelvis?" I attempted to prove the two following hypotheses :—

Firstly, " *That the development of arthrodial joints in the pubic symphysis and sacro-iliac synchondrosis of the female during the later months of pregnancy is a mechanical result of the presence of a heavy bulky mass in front of the spinal column during that period.*

I supported this statement by the description of analogous changes which are produced in workmen by carrying loads whose position bears the same relationship to the lumbo-sacral articulation as does the foetus in the pregnant female, and of the mechanical means by which these amphiarthrodial joints are raised to a higher stage of development during a portion of the lifetime of the individual. This theory received the assent of a very eminent authority on the mechanics of the female pelvis.

The *Second* hypothesis was of a more complex character. It was " *that a force which produces no obvious change in the skeleton of the antecedents, but only a tendency to change, can, acting as a developmental factor, cause the apparently spontaneous development of that change in the offspring.*"

I applied this theory to the skeleton of the trunk of the human female, and I attempted to show that the differences which existed between this portion of the skeleton in the two sexes were instances of it.

I will state them briefly.

(1) The presence of the foetus during the later months of

pregnancy, acting in the same manner as a dead weight occupying the same relative position to the column, *tends* to produce in the fully developed skeleton changes similar in character to those which are developed during the lifetime of an individual by the habitual action of a heavier load similarly supported, and that though this tendency to change may produce little or no change in the individual, it may determine the apparently spontaneous development of the change in the offspring.

The characters here referred to are the lesser depth of the sacro-iliac synchondrosis and of the pubic symphysis in the female subject, the lesser depth of the true pelvis, the difference in the shape of the sacrum, the slighter prominence of the lumbo-sacral angle, the altered direction of the plane of the facet on the upper surface of the sacrum, and of the superior articular processes, the different shape and development of the spinous process of the sacrum, the increased diameter of the conjugate of the outlet, and the variation in the greater extent of the sacro-sciatic ligaments.

(2) The fœtus, existing as a bulky mass during the later months of pregnancy, presses upon the lower portion of the thorax, distending it and diminishing its respiratory capacity. It consequently *tends* to produce an increased development of the respiratory capacity of the upper portion of the chest, as indicated by an increase in the spans of the upper ribs, in the breadth of the upper interspaces, and in the depth of the manubrium; to increase the interval between the symphysis pubis and the sternum, and consequently to diminish the length of the gladiolus; also to render the manubrio-gladiolar articulation very freely movable. The pressure exerted by the fœtus as it encroaches upon the fully developed thorax must tend to produce the above changes in it, and it is, therefore, quite apparent that these changes which are present in the female pelvis are the expression of the progressive or evolutionary tendencies in the antecedents as progressive actualities in the offspring.

(3) Again, in the same manner, the pressure which the bulky fœtus exerts upon the iliac bones *tends* to produce their expansion and flattening, with separation of their anterior superior spinous processes.

(4) Lastly, the fœtus, as it passes through the true pelvis, *tends* to increase its calibre and the size of the angle between the pubic and ischial rami, and to evert and render smooth the edges of these bones; also to separate the ischial tuberosities, and to alter the direction of the spinous processes of those bones.

If the above assumptions are true, it is obvious that the variations which exist between the forms of the pelvis in the two sexes, as well as of the rest of the skeleton of the trunk, are due to the weight of, and the pressure exerted by, the fœtus in the later months of pregnancy acting as an evolutionary tendency to change.

The difference in the forms exhibited by the pelvis and thorax in the several sections of the quadrumana can, in view of the knowledge which we possess of the changes produced in the human subjects by the carrying habitually of very heavy loads, be easily explained by a consideration of the attitudes habitually assumed by each group of animals. The same line of argument may be applied to the influence of the weight and pressure exerted by the fœtus in the quadrumana.

It must be quite apparent, in the transition from one type to another, that while the gradually and newly acquired habits of the parents *tend* to but do not actually produce in them an alteration in their anatomy, yet the tendency evolves the factor which *produces* in the offspring the actuality of the change.

I would point in support of this hypothesis to the gradual appearance of asymmetry of the costal cartilages and of the pleurostea of the sternum in the higher apes, and to its gradual disappearance in man. In a previous contribution to the *Journal of Anatomy and Physiology*,[1] "The Causation of several Variations and Congenital Abnormalities in the Human Subject," p. 594, I explained the manner in which this asymmetry was produced, and I showed that it was due to gradual change in the habits of the various groups of animals.

It must be quite apparent that in this instance the factors which, acting as a hereditary tendency to a change, brought about that change in the offspring, could not have produced its actuality in the parents during their lifetime.

The variations in the form of the skeleton of the trunk, and

[1] Vol. xxi., New Series vol. i. p. 586.

in the formation and detail of its component parts, afford another very strong argument in favour of this hypothesis.

We have only to compare this portion of the body in the several sections of the quadrumana and in man, and to observe the form of the thorax, the number of vertebræ above the sacrum, and the shape of the pelvis in the lower orders, and the alterations which these portions of the skeleton develop in the anthropoid apes, in accordance with the habitual assumption of acquired habits; and, again, the changes they undergo in man in consequence of the same cause, to become firmly convinced that the factors that determine these changes are purely and simply mechanical, and that they act as evolutionary tendencies to change, and not necessarily by the production of an actuality of the change in the parent.

I do not for one moment intend to suggest that, apart from the changes which I have shown to develop in joints and in the ends of the bones entering into their formation during the lifetime of an individual, in consequence of the habitual performance of a single function, there is no other actual change in the skeleton. On the contrary, I have found that bones will undergo remarkable changes in form during the lifetime of a single individual, owing to the habitual presence of a tendency to the development of one portion or portions of the bone rather than others, resulting from the habitual performance of certain definite movements. I do not refer merely to such obvious results of occupation as an excessive growth of the lesser trochanter of the femur, but rather to alterations in the form of such a bone as the scapula, and in the extent of development of its component parts. These alterations are not so readily noticed, and in the same proportion their causation is more obscure.

Broca, Flower, Sir William Turner, and other observers have called attention to the variations which the scapula presents in different races. Professor Turner concludes that to some extent the habits of a race will affect the configuration of the skeleton. In his paper "On Variability in Human Structure,"[1] the reader will find the subject fully discussed. I have found in the dissecting-room spines presenting quite as marked diminution in the convexity, or showing as distinct concavity, of the lumbar

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[1] This *Journal*, vol. xxi. p. 473; also "*Challenger*" *Reports*, part xlvii., "Human Skeletons."

spine as did those of the Australians, &c., which he describes. Is it possible that the habit of wearing heels is responsible for the greater convexity of the lumbar spine in Europeans? I hope in a subsequent paper to show that similar variations in the form of the scapula and of other bones exist in the inhabitants of our island, that peculiar variations belong to certain occupations which are commenced at an early period of life, and are carried on up to the end, as, for instance, that of shoemaking, and I also hope to be able to demonstrate with some accuracy the special group of habitual movements which determines each variation. Personally I am convinced of the accuracy of this statement, though it is obvious that it will require much time and trouble to obtain sufficient material to render it as complete as one would wish for purposes of demonstration.

There is also to be observed in man a still further degree of development, which I believe to be due to the acquired habit of wearing boots with heels, by means of which the direction of transmission of superjacent weight through the lumbo-sacral articulation is altered. I allude to the existence of an additional vertebra above the sacrum, due to a separation of its first piece. Associated with this dissociation of the first sacral vertebra there is an altered type of pelvis, a change in the form of the thorax and of the lumbar spine, &c. Observing these changes, it is again quite apparent that the acquisition of the habit could not have produced them in the parent, but that instead they produced in him a tendency to change, which resulted in the actuality of the change in the offspring.

Though, as has been frequently asserted, we do not get individuals who are definite examples of transitional types, yet we are able to recognise and observe in each group individuals possessing some of the characters which are regarded as characteristic of another group, and which show that a change in form is still going on in one apparently distinct group of individuals, and that this change can be distinctly observed and measured.

I will take man, as I know more about the variations in his anatomy than in that of other animals.

Among the bodies that come into our possession for the purpose of dissection, we observe that the majority of individuals possesses a certain average type of skeleton, which we are

accustomed to describe as normal, and that there is a small pro-
portion which possesses characters which are distinctive of the
higher apes, and are not sufficiently recognised in their entirety.
These characters we speak of as simian. The one usually
recognised is the union of the fifth lumbar vertebra with the
sacrum to form its first piece, and the diminution of the number
of vertebræ above the sacrum by one; and another very obvious
one is the asymmetry of the costal cartilages and sternal
pleurostea to which I have called attention. There are associ-
ated with this fusion of the fifth lumbar vertebra with the sacrum
very definite and obvious deviations from the so-called normal
type in the whole of the skeleton of the trunk, all of which
correspond in character more or less to those in the higher
apes. There are, I believe, associated also with these variations
in the trunk very definite changes in the remainder of the
skeleton; but though I have obtained some apparent proof of
this, I am not prepared to formulate them very definitely just
at present.

Now, between the distinctly simian type of skeleton and the
so-called normal skeleton, we get in man every degree of varia-
tion.

Again, in man we have, as I have already stated, a fairly large
proportion of individuals of the male sex whose skeletons pre-
sent variations from the normal, the most obvious of which is
the separation of the first piece of the sacrum to form an
additional vertebra above that bone.

As in the case of the simian type, so in this, I have found
that there is associated with this separation of the first sacral
vertebra a very distinct group of variations in the skeleton of
the trunk, and I believe also in that of the whole of the body.
There is between the normal type and the fully developed
variation just described every intermediate degree of develop-
ment.

I have observed that the human female pelvis, as seen in our
dissecting-rooms, does not display either of the conditions I have
described as dissociation of the first sacral vertebra or that of
fusion of the fifth lumbar and first sacral vertebræ. It is there-
fore obvious, that while the female skeleton assumes more
rapidly than does the male the form that may be regarded as

its normal type of pelvis, yet it resists in a remarkable manner the tendencies which succeed in producing change in the male, though it appears almost absolutely certain that it is subject to their influence. It is also apparent that the early assumption of the normal type by this portion of the female skeleton, and the resistance to change which it displays, are the products of the evolutionary or developmental tendency produced by the mechanical influence exerted by the foetus. Though the female pelvis does not undergo any apparent alteration in consequence of the influence of the mechanical factors which determine the change in the male, yet it may reasonably be supposed that the same factor produces a greater compensatory change in the remainder of the body than it does in the male.

I believe that exactly the same variations in two directions can be readily demonstrated in any race of the higher apes, and I think therefore that we may assume the same holds good for animals lower in the series.

It seems to me that we are wrong in looking for what is commonly called a transitional type, in the sense of an animal possessing characters exactly intermediate between one group and another,—for instance, between the supposed typical anatomy of man and of the higher ape.

If the hypothesis that I have laid down as to the transmission of a tendency being followed by its actuality, and that this tendency is always mechanical in character, be true, it is apparent that the acquisition of certain habits may cause one portion of the anatomy to vary in one direction and another portion in another.

This would account for the fact that we are unable to show absolutely that one race approaches more nearly to the higher apes in *all* its characters than another.

I was much struck by this in reading papers which interested me deeply in the *Journal of Anatomy and Physiology*.[1] It is obvious that in order to produce a type possessing characters intermediate between those of the higher ape and

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[1] "On Variability in Human Structure as displayed in different Races of Men, with especial reference to the Skeleton," by Sir W. Turner, vol. xxi., N. S. vol. i., also "The Sacral Index," Jan. 1886; "The Lumbar Curve of the Spinal Column in Several Races of Men," April 1886, vol. xx., &c.

of man it would be necessary that successive groups of individuals forming that highest order of apes be exposed continually to exactly the same variations of climate and surroundings, be made to follow exactly the same variations of pursuits, occupations, and habits, and to procure the same changes of food. By this means the anatomy of the race would be subjected to exactly the same mechanical forces, and identical tendencies resulting in identical actualities would result.

It is the reversing of this uniformity that has resulted in the present condition of the human race and in the absence of an intermediate type.

In a typical case of dissociated first sacral vertebra do we also find that the shape of the skull varies from what is regarded as the normal type, in a manner similar to that in which the component parts of the trunk do in response to the alteration in their mechanical surroundings, whether it be produced, as I believe it usually to be, by an alteration in the normal antero-posterior plane of the foot by wearing heels, or by any other cause which in a similar way modifies the manner in which superjacent weight is transmitted through the lumbo-sacral articulation ?

I am rapidly collecting material by means of which I think that I shall be able to prove this, namely, *that the form of the head, like that of the components of the trunk, and probably also of the limbs, will undergo a change in response to a variation in its mechanical relations to its surroundings.*

Another question arises if we assume that my hypothesis is true, which I believe it is, namely, Are the contents of the cranial cavity altered in their detail by the change in the form of the cranial cavity, or is the same brain merely packed in a different manner ?

Putting this question differently,—Is it possible to alter the detail of the brain by developing mechanical tendencies to growth in certain directions ?

I wont attempt to answer this question now, but will pursue the investigation in another direction.

In analysing the causation of the variations that exist between the form of the skull in the higher apes and in man, the nation of the changes in form is more complex than it

is in the case of the associated variations in the form of the several component portions of the trunk.

This is owing to the fact that in the cavities of the trunk the contents undergo no practical variation, but in the case of the skull, besides the presence of the mechanical factors which develop tendencies to change in consequence of the habitual assumption of the more or less erect attitude, there are associated progressive alterations in the arrangement and size of the cranium and of the cranial contents.

Another difficulty now arises in understanding how far the alteration in the form of the skull, which was consequent upon a change in the habits, surroundings, and necessities of the individual, was the direct mechanical cause of the assumption of the erect posture, and how far the alteration in form resulted from a mechanical tendency to the enlargement of the portion of the head above and behind the occipito-atloid articulation, as the result of a prolonged life and increasing experiences.

What I mean is that the alteration in the character of the food, surroundings, and necessities of the individual would exert a tendency to the diminished development of the prominent powerful jaws and the large projecting snout with its extensive mucous membrane.

Associated with this there would exist a tendency to the diminution of the large olfactory and other sensory centres which are placed anteriorly in the brain. As these tendencies become actualities in the offspring, it is quite intelligible that in consequence of these changes the animal will assume and retain the erect position with greater ease than did the parent.

The increasing length of life of the individual, and its associated increasing and varied experience, would tend to the increased development of that portion of the brain which is situated above and behind the occipito-atloid articulation.

It is possible, also, that the mere habitual assumption of the erect posture may of itself tend mechanically to the diminished development of the projecting jaws and snout, to a diminution in the development of the sense of smell, and to a consequent and necessary increase in the development of other portions of the brain.

It is, I think, apparent that changes take place in two

directions, and that in either case the manner in which they are produced is purely mechanical.

I might remind the reader that in a preceding paper I showed from the measurement of many human skulls that a considerable and variable asymmetry of this portion of the skeleton was very frequently present. In a very large proportion the left side of the skull was larger than the right, and in a small minority the left half was smaller than the right. I ascribed this to the increased experience which the right side of the body has acquired as compared to the left. In cases of apparently considerable asymmetry, it seemed to me that the skull was balanced by being placed somewhat obliquely upon the articular surfaces of the atlas.

We have only got to determine more accurately the manner in which the several component parts of the body respond mechanically to changing surroundings, and we will be able to explain not only the variations which exist between the forms of the skulls and other portions of the skeleton of different human races, but also the transition of the simian to the human type.

THE PHARMACOLOGY OF THE NITRITES AND NITRO-GLYCERINE.[1] By G. Armstrong Atkinson, M.D., *formerly Assistant to the Professor of Materia Medica in the University of Edinburgh.*

(From the Pharmacological Laboratory of the University of Edinburgh.)

THE nitrite group—including nitro-glycerine, which, although therapeutically closely allied, yet pharmacologically, as will be shown, presents important differences—is of considerable magnitude, a considerable number of nitrites being known. Those nitrites only, however, will be discussed which either specially show the action of nitrous acid in combination to form a salt, or are recognised as of value in medicine. Many nitrites, from their physical characters, or from the pharmacological activity of their bases, are unsuited either for experimental investigation as to the nitrite action or for clinical use.

Historically, the first nitrite of which we have mention is nitrite of ethyl—the discovery of this compound being accredited to Raymond Lully (1235 to 1315). He certainly was aware of the violent action of strong nitric acid upon alcohol, but he allowed, at all events, the bulk of the ether, the ethereal nitrous gas of the older chemists, to escape. Basil Valentine in the 15th century improved Lully's method; but both he and later chemists, speaking of the "spiritus dulcificatus," mean by this term the residue remaining in the retort after the reaction. The distillate apparently first had attention drawn to it by Kunkel in 1681, who termed it nitric ether in a letter to Voight. No attention was paid, however, to Kunkel's work until a process for obtaining the ether, or rather the impure alcoholic solution of it, was rediscovered in 1742 by Navier, and independently in 1746 by Sebastiani. After this period various modifications were introduced in the mode of preparation, and the impure alcoholic solution acquired considerable importance both as a domestic and as a more strictly professional medicine, the solution being known by various names, as the acidum nitri dulcificatum, sweet spirits of nitre,

nitre drops, hyponitrous ether, &c., &c. The British Pharmacopœia has adopted the name spiritus ætheris nitrosi—the spirit of nitrous ether.

But while, until far on in this century, this spirit of nitrous ether was the only preparation containing a nitrite used in medicine, the discovery of nitrite of amyl by Balard (*Ann. de Chimie et de Physique*, xii. 294) in 1844, and the work done at it by Frederick Guthrie (*Jour. Chem. Soc.*, xi. 245), by Richardson (*Reports of British Assoc.*, 1864 to 1871), and by a host of other observers, rapidly drew the special attention of scientific men and of medical practitioners generally to this body, and gave it a very important position among remedial agents. Furthermore, the investigation of the nitrite of potassium by Reichert and Weir-Mitchell (*Amer. Med. Sci.*, lxxx., 1880, p. 158); of the corresponding salt of sodium by Barth (*Toxik. Untersuch über Chilisalpeter*) and by Binz (*Archiv f. exper. Path. u. Pharm.*, xiii. 133); of the double nitrite of potassium and cobalt by Professor Leech (*Brit. Med. Jour.*, Nov. 28, 1885); and the introduction to medicine of nitro-glycerine, a body discovered by Sobrero in 1846 and investigated pharmacologically by Pelikan (*Beiträge*, 1858), and many others, have formed the important group now about to be considered. It will be found most convenient to examine the pharmacological actions of the nitrites proper and then proceed to those of nitro-glycerine.

The Pharmacology of the Nitrites.—The essential basis of pharmacological activity in this group of agents is nitrous acid. This acid has not been obtained in a pure state as a hydric salt (HNO_2), and it is questionable if a definite compound of this nature exist. In its anhydrous state it is a blue mobile liquid boiling at about 10° C., and rapidly decomposing as the temperature rises. Even very dilute aqueous solutions of the acid are only moderately stable. Solutions as weak as 1 in 3000 of water, kept at the ordinary temperature, gradually deteriorate, until in twelve or fourteen days the nitrous element has either entirely disappeared, or but the faintest trace is left. As some free nitrous acid is usually liberated in the stomach when nitrites are administered by the mouth, the stability of the acid in conditions likely to occur in the stomach was ascertained. Solutions of nitrous acid, when mixed with acid washings from rabbits' stomachs, decompose with a rapidity varying according to the temperature. Stomachs of freshly killed rabbits were laid open, the food carefully removed by a blunt spatula, and the mucosa of each viscus washed with 50 to 60 c.c. of warm distilled water. The strongly acid washings were mixed in

various proportions with a freshly-prepared 1 in 3000 solution of nitrous acid. It was found that in the cold (55° to 60° F.), complete decomposition of the nitrous acid did not occur with equal portions of the solutions for five to eight days. The nitrous acid entirely disappeared in from 30 to 60 minutes if the solutions were kept at 100° F., using in this case flasks fitted with inverted Leibig's condensers to avoid as far as possible loss of nitrous acid by volatilisation. With these conditions, using equal quantities of nitrous acid solution and stomach washings, no nitrous acid was, as a rule, to be detected after 30 to 40 minutes. If the mucosa itself were washed with the nitrous acid solution, the disappearance of the acid occurred in about a similar time, and the same held if the nitrous acid solution was mixed with an infusion from the food in the stomach. Further, in connection with absorption of freed nitrous acid from the stomach and its combinations in the system after absorption, it was ascertained that although the acid is chemically feeble, yet it can replace carbonic acid in carbonates and bicarbonates of the alkalies, and can convert part of the phosphate of sodium in a solution of that salt into acid phosphate of sodium and nitrite of sodium. When nitrous acid is added to ox or sheep blood, methæmoglobin is at once produced, just as with nitrites generally, and as with nitrites so with nitrous acid, the dialysation of such a mixture of blood and nitrous acid (unless the nitrous acid be in very minute quantity) gives reactions for a nitrite in the dialysed fluid. From what has been said, it is obvious that no accurate pharmacological work can be done with nitrous acid. The experiments carried out with it on myself, on frogs, rabbits, and dogs, showed its action to be identical with that of a simple metallic nitrite, as nitrite of sodium, in so far as the action of an acid can be considered identical with that of one of its salts. The salt with which most work has hitherto been done is nitrite of amyl, but the base (amyl) has a decided action of its own. It is therefore necessary, in order to ascertain the action of nitrous acid in combination as a salt, to select such a base as sodium, which has no well-marked pharmacological activity. The action of nitrite of sodium will therefore be considered in detail, and the action of some nitrites more or less compared with it.

THE PHARMACOLOGY OF NITRITE OF SODIUM.

The pharmacological literature pertaining to the action of nitrite of sodium is not great. Gamgee (*Proc. Roy. Soc. Edin.*, 1867, p. 168, and *Phil. Trans.*, 1868, p. 589) pointed out the resemblance in its action on the blood to that of nitrite of amyl, and various other authors have followed up his work as to the effects of nitrites on the blood. Brunton (*Pharm. and Ther.*, 1885, p. 636) states that from unpublished experiments he satisfied himself that the action of nitrite of sodium on the blood-pressure was similar in kind to, but less in degree, than that produced by nitrite of amyl. Various authors, as Hay (*Practitioner*, March 1882), Leech (*op. cit.*), and others, have recorded their experiments as therapeutists, showing a like similarity in action. Barth and Binz (*op. cit.*) have also done some work upon its general action. Binz shows, from experiments on dogs, rabbits, and esculent frogs, that the animals become atonic and drowsy; in dogs vomiting and yawning frequently are produced, and death occurs without convulsions. Rabbits and dogs exhibited almost regularly a tendency to diarrhœa, even when the nitrite was administered by subcutaneous injection. The autopsies of the rabbits and dogs revealed general congestion of the abdominal organs, and frequently in rabbits small ecchymoses in the mucous membrane of the stomach. Reichert also (*op. cit.*) states that he carried out some investigations as regards the general action of nitrite of sodium, and its effects on the circulation and nervous system. He finds it to be similar in action, so far as he went, to nitrite of potassium, a paper on which he published, and of which it will be necessary to say more afterwards. Ringer and Murrell (*Lancet*, ii. 1883) showed that in man throbbing pains in the head, and a feeling as though the head would split, were experienced after 15 grains of nitrite of sodium by the stomach. Nausea, with eructations, and occasionally vomiting, were also experienced. The nitrite of sodium used in the following experiments was recrystallised by myself from commercial specimens of the salt, and contained nitrous acid equal to from 99·2 to 99·4 per cent. of actual nitrite. The amount of nitrous acid was estimated by a modification of the permanganate process, which I read before the Royal Society of Edinburgh (*Proc.*, 1885–86, p. 643).

GENERAL ACTION.

A. *On Frogs.*

All detailed experiments on frogs were made on species of the *Rana temporaria*, winter and summer. Some general experiments were made on the *R. esculanta*, which showed exactly the phenomena occurring in the *R. temporaria*. The —ʻ ʻnum lethal dose for a frog, of 25 to 30 grammes, is ʻns (·00972 gramme), and the following experiment shows nomena produced :—

Experiment.—Feb. 28, 1887. Male frog, 28 grammes, temperature of room 60° F.

12 noon. 3 minims of 5 per cent. solution of nitrite of sodium were injected under the skin of the back in the neighbourhood of the posterior lymph hearts (= ·15 grain); no state of excitement was produced, and no irritation beyond what the prick would cause at the seat of injection.

12.2. Animal when irritated leaps less readily, and reflex movements are not so vigorous. Pupils slightly contracted.

12.5. Movements feebler; leaps only a short distance when irritated. Cutaneous vessels dilated, and their contents darkened. Respiration apparently unaffected.

12.10. Frog jumps very feebly and unwillingly. Pupils as large as before the experiment. Respiration rather slower.

12.15. Frog sits very quietly, with thorax only slightly raised from the table. The respirations are decidedly slowed. The cutaneous vessels well marked, and the blood in them is of a chocolate colour. The pupils are of the same size as when the experiment commenced. The lower eyelids are slightly closed. On pinching the legs a feeble reflex movement is produced, and if the pinching be strong the animal crawls away with a kind of feeble walking movement. It cannot be made to jump, and when placed on its back is unable to turn on to its belly, and after a few feeble struggles remains quietly in this position (*i.e.*, on its back).

12.20. Replaced on its belly, on which it lies prone. Strong pinching produces only slight movements of the limbs, and the animal, with great difficulty, can feebly move a short distance away by a crawling motion. Respiration slower.

12.25. In much the same condition.

12.45. Has become still feebler. Scarcely any response to irritation. Respiratory movements slow and feeble.

1.0. Respiration ceased. Pupils larger than before experiment. Lower eyelid about half covers the point of eyeball. Heart, sciatic nerves, and muscles of posterior extremities exposed. Blood markedly chocolate coloured. Heart—ventricle beating feebly—18 per minute. Auricles 36 per minute. Strongest stimulation of sciatics (Du Bois Raymond induction coil with one Daniel's cell) produced only feeble movements of the toes. All the skeletal muscles inexcitable except those of the thighs and of the legs, which very feebly responded to the strongest current. The heart was covered with blotting paper soaked in normal saline, and the spinal cord was exposed. No movement was produced by stimulating it. The heart beat until 2.30, when the ventricles ceased to contract, remaining in moderate systole. The auricles beat until 3.30, stopping in full diastole. Both auricles and ventricle responded to the strongest current until 4.10. At this hour the heart muscle was feebly alkaline. The reaction of the skeletal muscles at the time of stimulation, after cessation of respiration, was also alkaline. The lungs were somewhat collapsed, and of a dirty brownish-white colour, and their vessels were dilated. After the heart ceased to react to

electricity, the tissues were ascertained to give the tests indicating the presence of a nitrite, and from the blood on dialysation the same reactions were obtained. *Post-mortem* rigidity came on shortly after death. The following morning it was very pronounced—the pupils were mere pin-points, and the subcutaneous tissues, especially in the dependent parts, were somewhat œdematous. The *post-mortem* rigidity lasted the usual time.

Experiment.—When a similar dose is administered to larger frogs (35 to 40 grammes) the phenomena are closely allied to the preceding, but slower in their development, and not followed by death. In 20 to 25 minutes the animal is usually unable to jump or turn off its back. From this period onwards it gradually recovers, being much better in about one hour more, when it can jump fairly well. In 2 or 3 hours from the time of injection it is apparently normal, except a slight weakness is detectable. The following day it is quite well.

Experiment.—Smaller doses given to similar frogs produce a more passing but like degree of feebleness. In no case does any excitement beyond that prodeced by the injection occur, doses being administered down to the 100th part of a grain. With larger doses than those described the various stages occur more rapidly.

Experiment.—February 5, 1887. Male frog weighed 24 grammes. Temperature of room 62° F.

11.4. One grain nitrite of sodium in 10 minims of water injected subcutaneously in back. Animal almost immediately became sluggish in its movements, and leapt only when strongly irritated.

11.8. Respiration ceased. Heart exposed, and found beating very feebly.

11.15. Heart only giving an occasional beat. Both auricles and ventricle contracting. Cord, sciatica, and muscles all inexcitable. Blood chocolate coloured.

11.40. Ventricle ceased in moderate systole. Auricles still beating feebly. Ventricle very feebly reacts to the strongest current.

11.45. Ventricle inexcitable.

12.1. Auricles ceased in diastole and feebly react to the full current.

12.15. Auricles no longer react to current.

Experiment.—With still larger doses the heart ceased more rapidly. Frog weight, 22 grammes ; temperature of room, 29° F.

10.10. Three grains subcutaneously injected in 30 minims of water. Animal immediately gave a few feeble leaps and then became quite collapsed. Pupils somewhat contracted and lower eyelids half closed. Respiratory movements feeble and weak. The blood-vessels dilated. Heart seen to be acting very feebly. Blood dark chocolate colour.

10.15. Respiration ceased. Heart exposed. Beating feebly and slowly—auricles about twice as fast as the ventricle. Cord, sciatica, and muscles inexcitable.

10.25. Ventricle ceased in moderate systole and scarcely responds to full current.

10.28. Auricles ceased in full diastole and feebly react to full current. Ventricle inexcitable.

10.38. Auricle inexcitable. The other phenomena as already described.

It was further ascertained that the salt was rapidly absorbed from the skin, poisoning being readily induced by painting strong solutions of the nitrite over various parts of the body.

B. *On Rabbits.*

Experiment.—White rabbit, 4¼ lbs.

2.38. Four grains nitrite of sodium subcutaneously in 30 minims of water. Animal became immediately very prostrate, lying down on its belly with its limbs extended. Respirations very rapid and shallow. Ear blood-vessels, both arterial and venous, very prominent—the blood in them very rapidly assuming a chocolate hue. Pupils slightly contracted, the bright red of the pupils rapidly becoming of a dull reddish-brown. The pulse rate before injection was 29 in 10 seconds. Two minutes after injection it could not be counted owing to its extreme rapidity, and the reflexes were very decidedly diminished.

2.45. Pupils slightly larger. Animal much feebler. Blood-vessels, wherever visible, dilated, and blood in them dark chocolate. The mucous membranes dull livid in colour. Respirations somewhat slower.

3.0. Animal, which until now had remained quite quiet, cried feebly twice or thrice. Respiration rapidly slowed. The rabbit made slight movements with its fore-paws, and died at 3.2.

Immediate Post-mortem. — Venous system generally engorged. Arterial comparatively empty. Blood deeply chocolate coloured. Right ventricle in full diastole. Left ventricle in moderate systole. Both ventricles inexcitable to the strongest Faradaic current. Auricles gave an occasional feeble beat and continued so doing until 3.25, when inexcitable to electricity. Muscles and sciatics found inexcitable immediately after death. All the viscera congested. Small vessels of the intestines very well marked. All viscera dirty chocolate from the contained blood. Intestine contracted somewhat less markedly to the Faradaic current than the intestines of a freshly killed rabbit did. The bladder contained 5 drachms of urine giving the nitrite reactions very feebly. The urine contained no sugar and no albumen. The blood on dialysis gave nitrite reaction freely.

From further experiments on rabbits, the details of which it is needless to give, it was ascertained that as a rule rabbits of 2½ to 3½ lbs. require 3 grains of nitrite of sodium as a fatal dose by subcutaneous injection, death usually occurring within half an hour, and never preceded by convulsions more than those of a feeble dyspnœic character. Comparatively rapid recoveries occurred from doses just short of lethal ones, and after three hours or so a similar almost lethal dose might be given without causing death. In certain other rabbits, both of small and large size, doses from $\frac{1}{10}$ to 4 grains were intravenously injected.

These doses produced immediate and very pronounced prostration, or almost immediate death, according to the dose. No convulsive movements apart from feeble pawings occurred. In rabbits which were somewhat slowly poisoned *per orem* a tendency to looseness of the bowels and ecchymoses in the stomach were observed, but the actual diarrhœa, as mentioned by Binz, was not present. The looseness is probably due to retarded absorption and to transudation of fluid from the dilated intestinal vessels.

Experiment.—Rabbit, 4½ lbs.

11.0. Three grains nitrite of sodium subcutaneously injected. Animal rapidly became profoundly ill, presenting phenomena described above.

12.15. Animal still very feeble, but improving.

12.20. Fæces passed slightly softer than before injection.

12.30. Animal very much better. Four grains subcutaneously injected. The rabbit rapidly became extremely prostrate, and died quietly at 12.41.

Immediate Post-mortem.—Appearances as described previously, except that on the anterior and posterior walls of the stomach, especially towards the cardiac end, numerous small ecchymoses were present. None existed near the pylorus. The intestine contracted, much as in the previous rabbit, to the Faradaic current, and no ecchymoses were found except in the stomach.

C. On Dogs.

Two dogs were poisoned with this nitrite, one rapidly, the other more slowly.

Experiment.—Rapid poisoning. Mongrel bitch, 45 lbs., not fed in the morning.

12.1. Twenty grains of nitrite of sodium subcutaneously. Animal rapidly became lethargic, and at 12.15 lay on its side breathing quietly and rapidly; pulse 150 (before injection, 112). Eyelids closed, pupils markedly dilated. Skin feels hot, apparently from vascular dilation. Mucous membranes dingy red. Animal quite conscious.

12.25. Very feeble. When spoken to it merely wags its tail. Pupils dark coloured.

12.30. When spoken to it raised itself and endeavoured to walk, but was unable to do so.

12.40. Again attempted to walk, but fell heavily on its side.

12.42. Passed urine, containing nitrites.

12.50. Bowels opened, fæces softer than usual, considerable salivation. No attempt at vomiting. Respiration very rapid. Pulse could not be counted. Reflexes very feeble.

1.0. Bowels again opened, fæces somewhat looser. Dog apparently insensible. Pupils very small.

1.5. Began to moan, and moaned for two or three minutes. Animal becoming cold.

1.10. Respiration panting. Conjunctival the only reflex obtainable, except slight ear reflex.

1.15. Respiration slowing, and of a somewhat sighing character.

1.19. Animal took a long respiration with a kind of stretching movement of the whole body, and then ceased to breathe. The heart could be felt beating feebly for one minute and fifty seconds after cessation of respiration.

Post-mortem at 2 *o'clock.*—Mucous membranes dirty brown. Venous system engorged. Heart auricles and right ventricle dilated. Left ventricle in moderate systole. Heart inexcitable. Muscle reaction alkaline. Lungs chocolate brown, and pulmonary arteries full of blood. All the abdominal organs congested, and of a dirty chocolate colour. Bladder almost empty. Urine contained nitrites, but no sugar and no albumen. The intestinal canal contained much bile-stained mucus, but no fæces. Stomach contained no nitrites, but much mucus. Surface of stomach congested, and every here and there a slight ecchymoses present. No ecchymoses elsewhere in the body. Sciatics and muscles inexcitable. Muscles alkaline. *Post-mortem* rigidity both in rabbits and dogs appeared early, and was well marked.

Experiment.—Slow poisoning. Fox-terrier, 14 lbs., fed at 11.0.

12.5. Pulse 132. Respirations 20. Bladder emptied.

12.20. Six grains of nitrite of sodium injected subcutaneously.

12.28. Dog much depressed. Pulse 168, respirations 28.

12.45. Mucous membranes very livid. Dog continually yawning; sits quietly.

1.0. Dog very sick and salivated. Pulse 180, respirations 26. Reflexes markedly diminished.

1.10. Very feeble, walks with great difficulty. Superficial and deep reflexes greatly diminished.

1.23. Moaning occasionally. Passed about half an ounce of urine with nitrite reactions.

1.30. Pulse 178. Respirations 24.

3.0. Animal improving; pulse 132; respirations 30.

8.20. Dog very much better; can walk readily. Gave 9 grains of nitrite subcutaneously.

8.30. Blood pressure very low; pupils dark; pulse 132; respirations 26. Animal gradually became feebler, and died at 9.25.

9.45. *Post-mortem* as before, except that no ecchymoses were found in the stomach, and fæces were present in the large intestine.

D. *Personally.*

After taking 8 grains of nitrite of sodium by the mouth, in a few minutes I experienced a great tendency to faintness, with considerable acceleration of pulse, and a great lowering of the arterial tension. No sickness was produced, but the eructation of oxides of nitrogen continued for some time. The action was unaccompanied by any visible flushing of any part of the body.

ACTION ON THE INDIVIDUAL SYSTEMS.

The general action of nitrite of sodium shows that its action on the blood and on the circulatory system is of very high importance. The production of methæmoglobin by the action of nitrites on hæmoglobin has been established by the work of Gamgee, Hoppe-Seyler, Sorby, Lankester, and Jäderholm, and especially by that of Giacosa (*Zeits. f. Phys. Chemie,* iii. 54). The essential nature of methæmoglobin it is not proposed to discuss, but it is a more stable body than oxyhæmoglobin, the oxygen being more firmly combined. Methæmoglobin, by means of ammonium sulphide, and such reducing agents as accumulate in the blood in dyspnœa, is converted into reduced hæmoglobin. Its spectroscopic appearances are well known, and have been comparatively recently reinvestigated by such workers as Jolyet and Regnard, and by Henocque, but without any new facts being brought forward. The production of methæmoglobin, after the subcutaneous injection of nitrite of sodium, is comparatively rapid, and gives the blood its dirty chocolate appearance. Giacosa (*op. cit.*) has shown that the day after administration to dogs of nitrite of amyl there is no longer any methæmoglobin in the blood. He conjectures reduction occurs in the liver. With nitrite of sodium, disappearance of methæmoglobin is not so rapid as with nitrite of amyl,—probably owing to the great volatility of the latter. In the experiments I made, methæmoglobin was usually found present from 30 to 36 hours after the subcutaneous injection of 4 or 5 grains of nitrite of sodium in large dogs. The action of nitrite of sodium upon the form of the red blood corpuscles, and upon their size, is apparently negative. This was tested by comparing the corpuscles in poisoned and normal animals, and by examining the corpuscles of various animals in sulphate of sodium solution, with and without the addition of various strengths of sodium nitrite. The action on the white corpuscles was examined in blood from the newt's tail. The drug was employed in ¾ per cent. salt-solution, and its action compared with that of normal saline. 1 per cent. solution of the nitrite rapidly killed the corpuscles. In 4 or 5 minutes they became somewhat rounded and motionless. 1 in 1000 caused death in

15 to 20 minutes. The peculiar colour produced by nitrite of sodium, when mixed with blood, is therefore entirely due to the formation of methæmoglobin.

Action on the Heart.

In the Frog.—The rate of the excised heart was determined in normal saline, and the viscus was then transferred to solution of nitrite of sodium in normal saline. Without entering into any detail it may be stated that with 1 per cent. solution the heart ceased to beat (remaining in full diastole and being inexcitable to the Faradaic current) in 8 to 10 minutes; with 1 in 1000 in about 3 hours. With 1 in 10,000 death was very slow. No acceleration in the beat was ever observable. When solutions were directly applied to the heart exposed *in situ*, the phenomena were much as above. No preliminary acceleration occurred, and the viscus slowed more or less rapidly according to the strength of the solution—20 per cent. stopped the heart in 8 to 10 minutes. With such a solution the auricles ceased almost simultaneously with the ventricle. With weaker solutions, the ventricle ceased some minutes before the auricles. When watery solutions of the salt were subcutaneously injected (the frog being fastened on its back and the heart exposed in the usual way), the beats became gradually slower, without, as before, any preliminary quickening, the heart occasionally, as poisoning advanced, making long pauses in diastole, and the auricles frequently were observed to beat about twice as fast as the ventricle—the ventricular diastole occurring in two phases. The heart-beats could not even in the early stages of the poisoning be recognised as stronger. They seemed at once to become feebler, this immediate feebleness being due largely, if not entirely, to the want of blood from the great vascular dilatation draining the heart. To ascertain the influence of the drug upon the frog's heart without the disturbing elements of this vascular dilatation, Williams's apparatus (*Arch. f. exp. Path. u. Pharm.*, xiii. 1) was employed. Tracings obtained with this apparatus showed that with 1 of nitrite in 1000 of blood and saline a rapid fall in blood pressure occurred without any preliminary rise, the heart slowing and beating more and more feebly, death usually occurring in about 10 or 11 minutes. If

1 of nitrite in 10,000 were employed, a very slight rise for 4 or 5 minutes occurred in the blood pressure, followed by a slow fall, death occurring in 40 to 60 minutes. With 1 in 20,000, the slight rise lasted from 10 to 15 minutes and then fell slightly below normal, the heart continuing to beat with a very slow fall for some hours. Weaker solutions gave negative results. From a further study of the tracings it seems that the slight rise of blood pressure is due to a slight quickening of the heart's action rather than to an increase in the strength of the individual beat. In connection with the action of the drug upon the heart, it was deemed advisable to ascertain its action on the vagus terminations in this organ. The frog was tied down, its vagi exposed and divided. They were stimulated from time to time with the Du Bois Reymond induction coil, and the minimum amount required to stop the heart ascertained. The frogs were then poisoned with the drug, and the strength of current now required to stop the heart ascertained from time to time. It was found that no alteration of strength was needful either in the way of diminution or augmentation. The effect on the vagus terminations of the heart is therefore negative. The blood-vessels were measured by means of a micrometer. The arteries were found to become very markedly increased in size. The veins also became dilated, and a venous pulse was frequently observed. The capillaries were microscopically observed to increase in diameter proportionally to the arterial dilation.

To measure the outflow from the vessels pithed frogs were employed; a cannula—communicating with reservoirs maintained at a constant level and containing either normal saline or saline plus nitrite of sodium—was inserted in the aorta, and the veins entering the heart cut. The outflow was measured every minute by collecting the falling drops in graduated vessels. Solutions of various strengths were employed, and all solutions from 1 in 100 to 1 in 100,000 increased the rate of flow—in the latter strength even as much as from 16 to 18 per cent. One in 200,000 was found to be practically without effect.

EFFECTS ON THE CIRCULATION IN MAMMALS.

In rabbits and dogs the circulation, as in frogs, is profoundly affected, as is seen from the general action. Great vascular

dilatation with marked acceleration of the heart-beats occurs. That the blood-vessels are dilated is obvious from the description given and the general action. Kobert (*Tag. der* 58 *Versam. deut. Naturf. und Ærtze*, p. 425) has further shown that nitrite of sodium circulating in the blood in the well-known perfusion apparatus with warm chambers through the organs of various mammals produces dilation of the vessels. Some notes have been made on the general action on the increase in rapidity in the pulse in rabbits and dogs. From experiments on dogs the pulse-rate was found to increase within 5 minutes of the subcutaneous injection of 2 or 3 grains of nitrite of sodium to about half again its usual rapidity, and the same occurred in man.

Sphygmographic tracings merely confirmed the observations of previous writers, showing very marked lowering of the arterial tension, the lowering of the arterial tension continuing from 3 to 5 hours after administration of from 2 to 5 grains of the drug by the mouth in average healthy men. No flushing of any part of the body was ever observed. The darkening of the pupils in animals under nitrite of sodium has been noted. This is probably entirely due to the production of methæmoglobin and the circulation of the chocolate-coloured blood so produced in the choroidal vessels. Ophthalmoscopic observations on rabbits and dogs showed that with comparatively small doses —as a quarter to half a grain administered subcutaneously to rabbits—a very slight arterial dilation occurred, and the veins were slightly increased in size, becoming also somewhat flattened. With large, almost lethal doses, both arteries and veins became, after a doubtful slight increase, distinctly smaller, due probably to the intraocular tension overcoming the lowered arterial pressure. When the animal had returned, or almost returned, to its normal condition, no increase in size of the vessels was detected. Similar results were obtained with dogs, and, so far as a few observations went, in man also.

Investigations on the Blood Pressure.—These were carried out entirely on rabbits. Examples with small and large doses may be given generally.

Experiment.—Small dose. Rabbit, weight 4 lbs. Cannula in left carotid. Blood pressure before injection of nitrite, 118 mm. mercury ;

respiration soon becomes of a panting nature, and 20 to 30 minutes after injection of these lethal doses the respirations become slow, deep, and of a sighing nature—yawning frequently occurring. Cessation of respiration occurs a minute or so before the heart ceases. In rabbits the heart continues acting somewhat longer after respiration has stopped.

Effects on Temperature.

A large number of experiments were made on rabbits and dogs, both in animals tied down and in others allowed to move freely about during the experiments, the temperature being taken every few minutes for hours in the rectum. The details are too long to give. The general results were, that with small doses a slight rise of rectal temperature occurred, the thermometer being always inserted for some inches, and of course in each animal it was inserted precisely the same distance, all ordinary precautions being observed. The rise of temperature was rarely more than ⅓ of a degree F., and was probably due to vascular dilatation. With large doses the temperature fell without any preliminary rise being recorded.

(To be continued.)

ON SOME POINTS IN THE ANATOMY OF A MEGAPTERA LONGIMANA. By JOHN STRUTHERS, M.D., *Professor of Anatomy in the University of Aberdeen.* (PLATES X., XI., XII.)

PART II.

THE LIMBS.

(A) THE PECTORAL FIN.

1. PROPORTIONS AND FORM.—The measurements given in Table I. below show that the greater length of the paddle in Megaptera is obtained mainly in the digital part. In B. musculus the digital part is shorter than the arm and fore-arm together, in the proportion of about 2 to 3¼ (2 feet 1½ inch against 3 feet 7 inches). In Megaptera the proportions are reversed, the digital part being to the arm and fore-arm together as about 5 to 7 (4 feet 10 inches against 6 feet 9 inches). The measurements in the Table show that the greater actual length of the arm and fore-arm in Megaptera than in B. musculus is contributed in about equal proportion by the arm and fore-arm. These proportions are seen by comparing figures 6 and 13,

of the same length, the former that of Megaptera, reduced to $\frac{1}{24}$, the latter that of the 64-feet-long B. musculus reduced to $\frac{1}{16}$.

Form.—The paddle of B. musculus presents, on the *radial border*, only a gentle elevation opposite the distal end of the radius, and thence sweeps in an even convexity to the tip. On the ulnar side there is the considerable but gradual elevation at the pisiform cartilage, and thence to the tip the even concavity, giving the clean-cut edges and elegant form, smooth-edged, curved, tapering, and pointed, of the paddle in that finner (fig. 13), in striking contrast with that of Megaptera (fig. 6). It is seen from that figure that most of the projections on the radial border of the paddle of Megaptera are caused by the great size and lateral projection of the cartilages of the digital joints. These nodes are nine in number, and the reason for that number is seen. Node No. 1, that nearest the body, most abrupt on the proximal side, very great, and the longest, is caused by the projection of the end of the radius, and by the sloping away from it of the radial border of the carpus and of the index metacarpal. Nos. 2 and 3 are caused by the nodes of the index digit, No. 2 more gradual and not so high as No. 3. No. 4, a great hump-like projection, is caused by the expanded terminal cartilage of the index digit and the ending of that digit. It rises 4½ inches beyond the general outline of the border, and is most abrupt on the proximal slope. The hollow between it and No. 3 is very marked, like that of a deep saddle. The remaining five projections are caused successively by the now exposed nodes of digit III. No. 5 is low but better marked than No. 2; Nos. 6, 7, and 8 are prominent, No. 7 the most so. The well-marked hollows between are rather wider than the mounds. No. 9 is situated at about 9 to 10 inches from the tip, is gradual and less prominent.

On the *ulnar border* there is the usual great but gradual elevation over the pisiform cartilage, its highest part a little proximal to the radial elevation. The border then sweeps on, gently concave, without undulation till about 20 inches from the tip, where two true projections occur, caused by the 6th and 7th nodes of digit IV. The second of these rises 1½ inch, and is opposite the 8th prominence on the radial border.

Between it and the tip occur four or five little undulations, but they are not prominences with a solid foundation, merely slight wavings of the soft parts. Digit V. causes no projection; the prominence formed by the pisiform keeps the skin away from the first two nodes of the digit, and its third node does not project on the ulnar side. The border does not come near digit IV. till opposite its last two nodes, which project very sharply on the ulnar side, and thus cause the two ulnar prominences above described.

The prominences on the paddle of Megaptera are, therefore, unlike those on the head, not dermal, but owing to the adaptations of the bones and cartilages. Their presence in Megaptera but not in B. musculus is owing to the very much greater expansion of the digital cartilages in the former. On piercing with the exploring needle at the prominences and between them, along the radial border, cartilage or bone was reached at from ¾ to 1 inch from the surface.

2. TABLE I.—*Measurements of the Pectoral Fin and its parts, of the Megaptera longimana, and of the 50-feet-long Balœnoptera musculus.*

	Megaptera 40 feet.		B. musculus 50 feet.	
	ft.	in.	ft.	in.
Length of pectoral fin, attached, ...	...		...	
,, inferior border, ...	12	0	6	0
,, superior border, ...	10	3	4	2
,, along the middle, straight, . . .	11	8	...	
,, from head of humerus, when detached, .	12	0	5	11
Breadth, greatest, ...	2	8½	1	4
,, at middle,[1]	2	0	...	
Length of humerus and fore-arm, ...	4	10	3	7
,, carpus, ...	0	5	0	3½
,, digits, ...	6	9	2	1½
Humerus, length, ...	1	11½	1	5
,, greatest diameter of articular head, . .	1	0¼	0	8
,, breadth of shaft, at narrowest part, . .	0	9½	0	6¾
,, thickness at ditto, ...	0	6½	0	4½
Radius, length along middle, ...	3	0	2	2
,, ditto without epiphyses, ...	3	8½	2	0

[1] The breadths of the paddle of this Megaptera at various parts were, as follows, in inches:—At 18 inches from the body, 23 ; at 30 inches from the body, the broadest part, 32½ ; at the middle, 24 ; at three-fourths from the body, 18 ; at 12 inches from the tip, 12 inches.

TABLE I.—continued.

	Megaptera 40 feet.		B. musculus 50 feet.	
	ft.	in.	ft.	in.
Radius, breadth at proximal end below the epiphysis,	0	7½	0	6¼
,, breadth at narrowest part, ...	0	5¼	0	3¾
,, thickness at ditto, ...	0	4⅝	0	2½
,, breadth at wrist, above the epiphysis, . .	0	11¾	0	6¼
,, thickness at ditto, ...	0	6	0	3¼
Ulna, length, ...	2	6	2	0½
,, ditto without epiphyses, ...	2	3¼	1	11
,, breadth at proximal end, including bony olecranon,	0	6¾	0	6½
,, breadth at narrowest part, ...	0	4¼	0	2¼
,, thickness at ditto, ...	0	3	0	2¼
,, breadth at wrist, above the epiphysis, . .	0	7½	0	4⅝
,, thickness at ditto, ...	0	3	0	1⅝
Width of interosseous space, at middle, . . .	0	0¾	0	2
Breadth of radius and ulna together at wrist, . .	1	7	0	11¼
Carpus, length at middle, ...	0	5	0	3¼
,, breadth, with pisiform, ...	1	11½	0	11¾
,, ditto without pisiform, ...	1	6¼	0	9½

3. THE SCAPULA.—The scapula of Megaptera differs greatly from that of B. musculus in form, in being higher in proportion to its antero-posterior length, and in its upper border being more arched upwards, and in its thickness, but the chief difference is the absence in Megaptera of an acromion process, and in the rudimentary condition of the coracoid. A low thick spine is seen in much the same position as in B. musculus, marking off a very shallow prescapular fossa, about 2 inches in breadth; but this low spine disappears at 7 inches from the glenoid cavity, and there is not even a ridge where the acromion would have been placed. The coracoid projects only for 1 inch, but extends into the area of the glenoid cavity, forming the anterior and inner part of the cavity for a space of 3½ inches in width and 2 inches long-ways. The line of synostosis is still visible on the left scapula (fig. 8), but is nearly obliterated on the right scapula. The projection of the coracoid would be greater in the mature state, as on its low blunt end there is a triangular area 1½ inch by 1¾ across, which has been covered by cartilage.

The proportions of the scapula, actual and in comparison with those of B. musculus, will be seen from the measurements given in Table II. Its greater height in Megaptera, compared with its antero-posterior length, is well brought out by measure-

ments 1, 2, and 3 in the Table. The line between the anterior and posterior angles divides the height equally, while in B. musculus only about one-third of the height is above that line. The anterior border is shorter than the posterior, measured straight from either the end or the middle of the edge of the glenoid cavity. In B. musculus the anterior border is longer than the posterior taken from the ends of the glenoid cavity, owing apparently to the presence of the large coracoid and acromion processes. The

4. TABLE II.—*Measurements of the Scapula, given in inches.*

	Megaptera.	B. musc. 50-feet-long.	B. musc. 60½-feet-long.
1. Antero-posterior length, right, . .	42	39	...
,, ,, left, ...	41	38½	48
2. Height, right, ...	30	22½	...
,, left, ...	29	22	27
8. To upper border from line of antero-posterior diameter, . . .	15	9	11
4. To glenoid margin from ditto, . .	15	13	16
5. Anterior angle to anterior end of glenoid cavity, straight, . .	19	21	26
6. Posterior angle to post. end of ditto, .	22	19½	24
7. Middle of glenoid margin to anterior angle, ...	24½	23½	29
8. Ditto, to posterior angle, . . .	26½	23½	29
9. Glenoid cavity, length, . . .	12½	9	11
10. ,, breadth, . . .	9½	4½	7½
11. Coracoid process, projection, . .	1	4½	8
12. Ditto, breadth at middle, . . .	...	3	3½
13. Acromion process, anterior border, . .	...	7	8
14. ,, ,, posterior border, .	...	8	4½
15. Thickness of scapula at middle of upper border, ...	1½	0½.	0½
Weight of scapula, in ounces, right, .	558½	286	...
,, ,, left, .	528	255	480½

strongly and nearly uniformly arched form of the upper margin would be diminished in the more mature state, judging by the outline of the cartilage shown in the figures of Eschricht (xvii. p. 79) and that of Van Beneden and Gervais (Pl. X. and XI. fig. 6). These imply that the posterior angle would be elongated, and the upper border near it filled up and more flattened by farther ossification. The figure of Rudolphi (Taf. i. fig. 1) shows this to some extent. But the cartilage in B. musculus would also

render its border still more straight. In my 64-feet-long B. musculus there was but a narrow strip of cartilage along most of the border, enlarging into a triangular plate behind and before, covering the more curved parts of the posterior and anterior ends of the bone, and forming a nearly straight upper border, with a little curving down at the posterior angle, the cartilage at which was the largest. D'Alton's figure of the scapula of Megaptera (Taf. iv. fig. f.) is the likest to the scapula of this Megaptera of any of the figures given; but in his figure the anterior border is longer than the posterior, and the anterior angle is blunted. On the anterior border of my Megaptera, internal to the junction of its lower and middle thirds, there is a gentle elevation, 3 to 4 inches long, with a rough summit, shown only in the figure of Megaptera Lalandii of Van Beneden and Gervais (Pl. IX. fig. 4), scarcely to be recognised in B. musculus.

The Upper Border.—When these scapulæ are placed in pairs on the floor, standing on their glenoid cavities, various differential characters come into view; the relation is seen of the different thicknesses and curvatures of the upper border to the stronger and thinner parts of the body and to the curvatures of the surfaces. The much greater thickness of the upper border and of the whole bone in Megaptera is striking. In the 60½-feet-long B. *musculus* the thick parts are, in front for 8 inches (increasing from ½ inch to 1 inch forwards), the front half of that much bent down; and behind for 16 inches (increasing from ¾ inch to 1¼ inch backwards), the hinder three-fourths of that much bent down. These thick parts appear as if incompletely ossified, as when denuded of cartilage. The long (32 inches) intervening nearly straight part of the border is thin, from ½ to ¼ inch, mostly ¼. These thick fore and back parts are also somewhat bent outwards, giving a moderate outward concavity to the border where each of the two thick parts meets the intervening thin part, but the general effect is a slight concavity outwards of the whole border. The two thick parts are seen to be the ends of the anterior and posterior beams of the scapula, the anterior beam strengthened by the spine of the scapula running up to it at the anterior angle. The same thick parts and curvatures are seen in the

50-feet-long B. musculus and in B. borealis, but in the latter the anterior and posterior angles are bent rather inwards.

In *Megaptera* the whole upper border is of great thickness, except for about 9 inches just in front of the middle, where it is of but moderate thickness. The thickness of the hinder half (27 inches in length) increases backwards from 1¾ to nearly 2 inches. The anterior thick part (18 inches in length) increases in thickness forwards from 1 to 1½ inches. The thinnest part, above defined, is ¾ inch thick. The posterior half has a marked general curve, concavity inwards, the bay 1 inch deep. The anterior half is gently sigmoid, the thinner part concave inwards, the anterior and greater part convex inwards. Thus the anterior angle is bent outwards as in B. musculus, while the posterior angle is bent inwards. There are thus on the inner side of the border two well-marked concavities, one on the posterior half, the other just in front of the middle; but on the outer edge the convexity corresponding to the anterior concavity is very little marked, owing to the thinning on the thin part being on the inner side. The beams of the scapula, reaching up to the thick parts on the border, are thus seen to be broader than in B. musculus, the only thin part of the whole scapula being that ascending from before the middle of the glenoid cavity to the thin part of the border, showing itself as a hollow in both directions on the outer surface of the bone.

In Megaptera, the *thickness of the bone* increases on about its upper third, so that the border, all along, is thicker than the part of the bone near it. But in B. musculus, the thickness continues to diminish upwards to the border, all along, except where the border is very thick, close to its posterior and anterior ends.

Viewing now the *surfaces* of the scapula, the inner (venter) presents none of those sharp ridges, radiating from the neck, which are so well marked in *B. musculus*. In it they are seven or eight in number, two running from the anterior border, the others radiating from the neck, better marked on the anterior than on the posterior half of the venter, and fully as well marked in the 50-feet-long specimen as in the more mature ones. These ridges, with their intervening fossæ, give the whole surface of the venter a fan-like appearance. Viewed as a whole the

venter in B. musculus has, apart from what is given by the rise towards the glenoid margin, very little concavity. Traced upwards from the neck, it is at first concave, then convex. That convexity is very strongly marked in my 64-feet-long specimen, so as to give a second concavity towards the top. Viewed longitudinally, the venter is, on the whole, convex, owing to the bending outwards of the angles, but, for about the middle half or more, between the anterior and posterior beams, there is some general concavity, about ½ inch deep, with depths of about 1 inch at the fossæ between the ridges. A general concavity of the venter is better marked in B. borealis to a depth of 1¼ inch, and it has the same radiating ridges as B. musculus, though they are less prominent. In *Megaptera* the venter, traced vertically, is, above where it is influenced by the neck, almost flat except along the middle part where the bend outwards and broadening at the top causes a slight vertical concavity. Traced longitudinally, the posterior beam, occupying the posterior half of the bone, shows a shallow concavity along its middle following the great convexity here on the dorsum. Another shallow concavity runs up between the two beams, at about the junction of the anterior and middle thirds of the bone, corresponding to the thin part of the upper border and to part of the great concavity on the dorsum. But the whole ventral surface strikes the eye as flat and smooth compared with that of B. musculus. Taken from the glenoid margin, the venter has a depth, in Megaptera, of 2 inches; in the 50-feet-long B. musculus, ¼ inch less; in the 60½-feet-long one, ¼ inch more than in Megaptera. The absence of the radiating ridges for the intermuscular septa of the subscapularis muscle, would seem to indicate a less development of that muscle in Megaptera. The greater thickness of the bone has as it were filled up the radiating fossæ between the ridges, but the ridges were no less necessary for the fibrous septa which so much increase the origin of the muscle.

The *dorsal surface* in Megaptera is more simple. Traced longitudinally, it is convex at each beam, the posterior convexity occupying about half, the anterior about a fourth, of the whole surface, with a marked concavity between, corresponding to the thin part of the upper border. A line between the most

prominent part of the two convexities gives a bay nearly 1 inch in depth. Traced vertically, there is very little concavity on the upper part of the surface, except on the posterior third. Taken from the glenoid margin, the concavity of the dorsal surface is 3½ inches deep at the great hollow between the beams, 2½ inches deep at other parts. The greatest depth of these fossæ is at about the junction of the lower and middle thirds of the bone. In *B. musculus*, the characters on the dorsum also are different. Traced antero-posteriorly, there are the convexities of the anterior and posterior beams, between these a wide general concavity, about 1 inch deep, intersected by a vertical ridge at about the middle of the bone, corresponding to one of the deepest radiating fossæ of the venter. Traced vertically, the upper part of the surface is a little concave on the anterior third, convex on the posterior third. Taken from the glenoid margin, the depth of the concavity of the dorsal surface is, high up on the anterior third, 2¼ inches, on the rest, about 1½.

The *glenoid cavity* is not only longer than in the mature B. musculus, but is broader in proportion to its length, as seen by the measurements given in Table II. The greatest diameter of the articular head of the humerus in Megaptera is 12¼ inches, that of the 60½-feet-long B. musculus is 9½ inches. The greater breadth of the glenoid cavity in Megaptera, as regards outline form, is gained on both sides, but the neck and cavity project more to the outer than to the inner side, to the extent that ⅔ of the breadth of the cavity lies to the outside of the plane of the bone. This is not the case in B. musculus, in which the projection to the two sides is either equal or greater to the inner than to the outer side. This difference may be in part owing to the presence of a large coracoid in B. musculus, and to the absence of an acromion process in Megaptera, but it is seen further back and is well marked.

Weight of the Scapula.—The greater robustness of the scapula of Megaptera is shown also by the weights given at the foot of Table II. In the 40-feet-long Megaptera it weighed 528 oz., against 255 oz. in the 50-feet-long B. musculus, and against 480¼ in the 60½-feet-long B. musculus. The difference between these two latter is also striking. The right is heavier than the left

in Megaptera by 30½ oz., and in the measurement (that given in the Table) is 1 inch higher and 1 inch longer than the left. The right in the 50-feet-long B. musculus is 31 oz. heavier than the left, and is ½ inch higher and ½ inch longer than the left. The left in the B. borealis is the heavier, by 141 oz. against 135 for the right. The left has an additional piece behind, giving it a length of 30 inches against 28½ for the right.

5. THE HUMERUS.—Viewed from the shoulder, the articular surface of the head of the humerus seems more extensive relatively than in the other finners. This is owing to the articular surface in Megaptera advancing more than in them towards the flexor aspect. Hence the head in Megaptera is placed more on the end of the bone, although its projection to the exterior aspect, and olecranonwards, is not less than in other finners. The epiphysis of the head forms nearly a third of the length of the bone.

Where the articular cartilage of the head, and that of the tuberosity, had lain, the rough appearance of the bone is very striking; perforated by numerous vascular apertures, admitting a crow-quill or thick pin, the apertures surrounded by elevations, forming irregular prominences as thick as the end of a little finger, and joining each other in a network, rendering the whole area tubercular, pitted, and perforated.

6. THE FORE-ARM.—Besides by their greater length and thickness, as compared with those of this 50-feet-long B. musculus, as seen in Table I., the bones of the fore-arm in Megaptera may be recognised by marked differences in form. This is more strikingly seen by comparison with the paddle of my full-grown B. musculus (this *Journal*, 1872), 65 to 66 feet long, the paddle from head of humerus to tip 7 feet 8 inches, in which the radius, omitting the epiphyses, has precisely the same length as in this 40-feet-long Megaptera with a 12-feet-long paddle.[1]

The *radius* of Megaptera is less bent, is narrower along the

[1] In connection with the description of the bones and joints reference may be made to figure 6, in which the left paddle, flexor aspect, of this Megaptera is shown, reduced to ¼₄, in which I have endeavoured to represent all the parts with exactness; and, for comparison, to figure 18, showing the same aspect of the left paddle of the 64-feet-long B. musculus, reduced to ¼₅, also drawn by me from nature.

proximal third, expands greatly in breadth towards its carpal end, and is thicker throughout. At the carpal end the breadths are 11¾ inches in Megaptera, in this full-grown B. musculus only 8⅝. This expansion in Megaptera renders the lower border of the radius very concave along its distal half or third. In the 50-feet-long B. musculus there is very little concavity there; in my 64-feet-long B. musculus (this *Journal*, 1871), the concavity is more marked, and most so just below the middle of the bone, but is not to be compared to the great concavity towards the wrist in Megaptera. In the 65 to 66-feet-long B. musculus the radius is convex throughout on this border, except just after the proximal end.[1]

Ulna.—The differential characters of the ulna in Megaptera are, the much shorter and much less expanded olecranon, its shortness at the carpal end compared with the radius, the more bent shaft, and the greater expansion at the carpal end. The breadths at the wrist are in Megaptera 7½ inches, in the 65 to 66-feet-long B. musculus 6½. The ulna falls short of the radius at the wrist, in Megaptera by 3 inches, in this B. musculus by 1¼ inches. The *bony* olecranon in Megaptera is a short blunt process projecting 1 to 1½ inches beyond the humerus, with an abrupt oval end, 3 inches in length, 2½ in thickness. In this 65 to 66-feet-long B. musculus, it projects 5 inches beyond the humerus and expands to a breadth of 12½ inches. In the 50-feet-long B. musculus, the bony olecranon projects 2½ inches, and expands to a breadth of 7 inches, the future recurved part represented as yet only by cartilage. In the 65 to 66-feet-long B. musculus this great bony olecranon reaches for 5 inches along the ulnar border of the humerus, forming a nearly rectangular socket for this part of the elbow-joint; in Megaptera not at all, leaving the here recurved epiphysis of the

[1] By the above characters I am able to recognise a large cetacean radius which came to Leith some years ago in a cargo of guano, as that of a full-grown Megaptera. Length, epiphyses consolidated, 37 inches; breadth at wrist 12, probably 13 inches, as it is somewhat injured here ; thickness at wrist, 7 inches. On section it is seen that there is no medullary canal, but cancellous tissue throughout. The cancelli are more open at the second quarter of the bone than at any other part. There is a layer of dense tissue at the radial end, ¼ to ½ inch thick ; and along the middle half of the shaft the tissue may be termed dense for ½ to ¾ inch at the surface, but not quite dense, and with gradual transition to the cancellated part.

humerus exposed for 3 inches. The *cartilaginous* olecranon in the 65 to 66-feet-long B. musculus is 7 inches in height, 9 inches in length at the top. In the 50-feet-long B. musculus, the height is 6 inches along the middle, the length at the top 7 inches. The dimensions of the cartilaginous olecranon in this Megaptera were not noted when it was moist, but it was much shorter and narrower than in B. musculus, and now, in the dried condition, it is 4 inches in height and the same in length, and has probably shrunk about 1 inch in both directions.

The *interosseous space* of the fore-arm is much narrower in the Megaptera than in B. musculus. At the middle, the width in Megaptera is ¾ of an inch; in the 50-feet-long B. musculus fully 2 inches; in the 65 to 66-feet-long B. musculus ¼ inch less, this probably owing to the greater thickness of the bones. In Megaptera it is rather wider (1¼ inch) just below the heads of the radius and ulna, and thereafter remains pretty equable at ¾ inch, lessening to ½ inch just before the epiphysis of the ulna. In B. musculus it narrows a little towards the elbow, and beyond the middle diminishes gradually by the expansion of the radius, and ceases a few inches from the carpus, the borders becoming flattened for contact of the bones. This flattening is 5 inches in length in the 65 to 66-feet-long B. musculus, 2 inches in the 50-feet-long B. musculus, but the actual contact appears to have been for about half of these lengths. In this Megaptera there is no flattening of the interosseous borders and no contact of the radius and ulna, the shaft of the radius resting on its ulnar side on the forward-projecting part of the ulnar carpal bone. This narrowness of the interosseous space in Megaptera is in part due to the less concavity of the radius, but mainly to the greater curvature of the ulna. The curve of the ulna is on both its borders. A line drawn from the ulnar edge of the humerus to the upper edge of the ulna at the wrist gives in Megaptera a bay 4 inches deep; in the 65 to 66-feet-long B. musculus, 3 inches; in the 50-feet-long B. musculus, 2½.

The fore-arm of Megaptera is still more differentiated from that of Mysticetus, in which the bones are comparatively short, the radius broad and flat, and the interosseous space wide.

7. THE ELBOW-JOINT.—The elbow-joint was diarthrodial, with one large synovial cavity. The cavity was continued on the

olecranon for 2½ inches (1¾ of it on the cartilaginous olecranon),
with a partial deficiency across the sigmoid cavity, as in man;
and was also continued in between the ʼepiphysis of the radius
and ulna for 1½ inches. The facet of the humerus for the
radius is almost flat; that for the ulna concave both ways, the
hollow ½ inch deep, till near the olecranon part where it be-
comes convex. The synovial membrane of the elbow passed
over the edges of the bones for ¼ inch, until it met the liga-
ments. The elbow-joint allowed of a very little gliding motion.

8. THE CARPUS.—The carpus has six cartilages, representing
bones, four in the proximal row, the radiale, intermedium,
ulnare, and pisiforme; two in the distal row, in series with
digits III. and IV. (see figures 6 and 9). Only the radiale
and ulnare have ossification, seen only in section. The posi-
tion and relative size of these small ossifications are shown in
figure 9, as are also the ossification within the epiphysis of
the radius, and the very small ossification within the epiphysis
of the ulna. The cartilages representing the future carpal bones
are well marked out on both the flexor and extensor aspect by
surface grooves, bridged over by fibrous tissue, and the separa-
tion of the cartilaginous blocks goes through and through, the
narrow interval occupied by soft connecting fibrous tissue,
resisting the handle of the knife and allowing of a little motion.
This is beautifully seen on horizontal section of the entire
carpus, the great blocks of cartilage mapped out sharply as in
an outline diagram. The numerous vascular perforations are
seen over the whole area of the cartilages. The lines of articu-
lation, occupied by the soft fibrous tissue, vary in width from
$\frac{1}{16}$ inch to half that or less. The same kind of articulation, by
intervening fibrous tissue, is seen at the wrist-joint, but with a
somewhat wider interval (about $\frac{1}{12}$ inch), and at the carpo-
metacarpal articulations.

Synovial cavities exist at both the proximal and distal ends
of the cartilage of the second row (os magnum) which supports
digit III. The proximal of these cavities reaches across the
whole breadth of the end (2 inches). The distal cavity covers
only about a fourth (1 inch) of the distal end, where the
cartilage forms a blunt peak. Both of these synovial cavities
go through and through from flexor to extensor aspect. It will

be observed that these diarthrodial joints occur on the ends of that carpal cartilage which supports the great digit.

On section, the separation of the ulnare and intermedium is less striking along the proximal half of their articulation, but it exists, and there are the usual surface grooves on both aspects. No separation is visible between the pisiform and the epiphysial cartilage of the ulna along the proximal ⅔ of their relation, but the surface grooves are complete. A faint groove, or break, appeared on the surface seeming to subdivide the very broad ulnare into an ulnar and a radial portion, but as on section and on slicing near the surface no trace of separation could be seen, it was probably unnatural.

Comparison with the Carpal Bones of other Whales.—As I hope to go into this subject fully in a subsequent paper, a short statement may here suffice. Megaptera differs from the other finners, and from Mysticetus, in the enormous extent of the ulnare (cuneiform bone), reaching as it does to opposite the ulnar fourth of the carpal end of the radius, and expanding to meet the short ulna. It has thus more than twice the breadth (10 inches) of the intermedium (semilunar bone) and radiale (scaphoid bone) together (about 4 inches each), and is also, from fore-arm to metacarpus, the longest carpal cartilage. The ulnare in the other finners does not reach to opposite the radius. The two cartilages of the distal row (os magnum and unciform) are much in the same position as in the other finners, but in B. musculus the trapezoid bone, or cartilage, is present, though not in B. borealis. The separation of the pisiform cartilage from the epiphysis of the ulna is complete in B. borealis. In the 50-feet-long B. musculus it is not so marked in the proximal as in the distal half of the articulation, but it exists. I would not regard the incomplete separation of the pisiform cartilage as a character of Megaptera. It is the same in my half-grown B. rostrata.

The epiphysis of metacarpal V. in Megaptera might readily be taken for a carpal cartilage, and when the bony metacarpals are removed so might the epiphysis of metacarpal II. It is notable that though digit II. is so much more massive in Megaptera than in other finners, there is no trapezoid, much less a trapezium, bone present in it.

In both the 50-feet-long B. musculus and the B. borealis, the carpal bones are well ossified, especially those of the first row, except the pisiform which remains entirely cartilaginous in all of them. This contrasts with the little progress ossification has made in the carpus of this 40-feet-long Megaptera.[1]

9. THE CARTILAGES AND JOINTS OF THE DIGITS.—The cartilaginous enlargements between the digital bones are greatly developed in Megaptera. Each of these nodes is composed of the two epiphysial cartilages, separated by a more or less developed synovial cavity.[2]

Mode of Articulation.—The perichondrium enveloping the node is, like the periosteum, about ⅜ inch thick, and, without removing this membrane, a transverse depression is seen indicating the presence of a joint. In the earlier nodes the position

[1] *Vascular Canals of the Cartilages in Cetacea.*—It may be noted here that these and all masses of cartilage in cetacea are pervaded by channels for red blood-vessels, resembling the system of Haversian canals in bone. On separating the epiphysial *cartilages of the digits* from their phalanx, the contained blood-vessels are seen like a system of cordage passing from the bone into the cartilage, stretching for about an inch before they give way. In vertical transverse sections they are seen as rounded apertures, with occasional communications, the apertures from ⅛ to ¼ inch apart, giving a perforated appearance to the whole area. In horizontal sections they are seen as a system of longitudinal canals, with anastomoses. In vertical longitudinal sections (flexor to extensor aspect) they appear fewer in number, some transverse but mainly longitudinal; seemingly none vertical, as if the vessels did not enter from the surface, but on the two surfaces are seen a moderate number of apertures of considerable size. The channels advance from the bone to the joint and are seen from the synovial surface as dimples with a thin covering. These may readily be converted into and mistaken for apertures. They give the synovial area a mottled appearance. In horizontal section through the middle of the *carpus*, the blood-channels are seen throughout the great masses of cartilage, at distances of ⅛ to ¼ inch apart, some cut transversely, most cut obliquely, as if going in from the surface, with anastomoses. On vertical section, not many are seen going in from the surface, but on the surface itself a number of large apertures are seen. The blood-vessels of the carpal cartilages must come from the surface, and the blood-channels within the cartilages seem to form a system striking in vertically but forming an anastomosing network.

[2] We make much of the fact of the epiphysis in man and various mammals being distal on the metacarpal bones and proximal on the phalanges. I called attention in 1863 (*Edin. New Phil. Jour.*, July 1863) to the fact, with which I had been long familiar, that in the cetacea there is an epiphysis at both ends of each phalanx and also at both ends of each metacarpal bone. This epiphysis at both ends of all these bones may be readily seen in an ossified condition in the paddle of Globicephalus melas and of the common porpoise. But I have not found it in an ossified condition in any whalebone whale, and Megaptera is no exception to this

of the cavity is proximal to the middle of the node; this is very marked in both the nodes of the index digit, while in the more distal nodes it is rather distal to the middle of the node. On dividing the perichondrium the cavity opens freely, exposing the two smooth synovial surfaces, and extends over the whole of the ends, except in the three distal nodes of the two great digits (III. and IV.) and the distal node of digit V., in which it does not reach quite to the extensor surface or fully to the sides, especially not on the side to which the node projects most. But the depression indicating the line of the joint is seen equally on the extensor surface. The part not separate is occupied by soft fibrous tissue, showing as a white line on section. As bearing on the incompleteness of diarthrodial articulation in the above-mentioned more distal nodes, it may be remarked that these nodes themselves are flexible, being flat and thin compared with the more proximal nodes, which are very thick.

Form of the Articular Surfaces.—The surfaces are generally slightly concavo-convex, the convexity generally on the proximal cartilage, but the curving is less in the direction between the flexor and extensor aspects than transversely in the direction from digit to digit. This departure from the flat in the inter-phalangeal joints is less in the more proximal nodes. At the metacarpo-phalangeal joints the surfaces are more nearly flat, or are sinuous, varying as follows:—The metacarpal is, on the index digit, slightly convex; on digit IV. slightly concave; on digits III. and V. it is sinuous, the concavity on the ulnar half in digit III., on the radial half in digit V. The metacarpo-phalangeal joints of digits II. and IV. are nearly opposite to each other in the limb.

The Digital Joints in Megaptera in comparison with those of other Whales.—The synovial cavities are well developed in Megaptera. In my 64-feet-long B. musculus the cavity, indicated on both surfaces, extended across only the middle third or less, of the node, and was absent in the smaller nodes. In Mysticetus there are the surface furrows and there is motion between the two parts of the node, but the boundary, which is seen through and through, is not effected by a cavity but by a layer of very soft cartilage.

Even when synovial surfaces occur in cetacean digits, the motion can be only that of a little gliding on the nearly flat surfaces. The cartilaginous nodes of the digits provide, by the flexibility of the substance itself, for a certain amount of general bending along the distal part of the paddle.

The Terminal Cartilages of the Digits.—The terminal cartilages of digits III. and V. resemble each other in that there is a cartilage attached to the distal bone, and a joint across part of the cartilage. In *digit III.* the cartilage attached to the distal end of the 8th bone is horse-foot shaped in outline, 2⅝ inch across by 1¾ longitudinally (fig. 10). The joint is situated ½ inch from the tip, is 1¼ to 1½ inch in breadth, reaching to ½ inch from the radial border and nearer to the ulnar border, and goes through the whole thickness of the cartilage. It is curved, the concavity towards the bone. The joint is a soft part of the cartilage, and permits of motion. This joint had the same position in both right and left digit III.

In *digit V.* the cartilage, attached to the distal end of the 4th bone, is ovoid in outline, wanting the proximal fourth of the ovoid where it is fitted on the phalanx; is 1¾ inch across and 2⅝ longitudinally. The joint is situated about ¾ inch from the junction with the phalanx, occupies the greater part of the breadth, is sinuous but mostly with its concavity towards the bone, and the cartilage bends at it readily. It was, however, seen only on the flexor surface, and, on section, to go only a third to half-way in from that surface. This was on the left paddle; in the right paddle no joint could be detected in the distal cartilage of digit V.

In *digit II.* the cartilage, attached to the distal end of the 3rd bone, is very greatly expanded, is of broad horse-foot shape in outline, 4½ inches across, 3 inches longitudinally (fig. 11). This cartilage forms most of the great hump on the radial border of the paddle, is about midway between the radial hump and the tip, and must give not only breadth but strength and resistance to this part of the paddle. It presents *two joints*, dividing it transversely and incompletely into three nearly equal parts, the proximal of the two the most marked. They are in part diarthrodial, in part formed by soft connective tissue. Both have the concavity proximal, parallel to the end

of the bone and to the distal border of the cartilage. The proximal joint is a cavity for more than the middle half of the breadth of the cartilage, and for the rest is soft connective tissue. Towards the radial side, the line of the joint, in the left paddle, makes a bend with the concavity distal on the radial fourth of the joint; in the right paddle, it is bifurcated there like the letter $\prec$. The distal joint occupies about the middle half of the cartilage and presents a central synovial cavity. It was noticed only on section. The preserved sections show the elliptical synovial cavity of the distal joint concealed on both surfaces, and the proximal joint as a more developed synovial cavity, indicated by furrows on both the flexor and extensor surfaces, but the cavity may be interrupted in part by soft fibrous tissue (fig. 12). As this distal joint would have been overlooked had the surfaces only been examined, we see how the commencement of an additional phalanx, or the existence of a phalanx potentially, may be overlooked.

In digit IV., after the 7th node, there is a solid cartilage, $2\frac{1}{4}$ inches in length by 2 in breadth, which might pass for a repetition of the 7th bone, or of the 8th bone of digit III., but for greater enlargement at its distal end, on the radial side. It is plainly the 8th bone of the digit as yet unossified. Then, with a joint between, comes a narrower cartilage, 2 inches in length by 1 inch in breadth.

Interpreting these terminal cartilages and their joints, the cartilage and its dividing joint in digits III. and V. might be described simply as the parts of a node in a flattened form, with its rudimentary joint. If more phalanges are to be formed, then the part distal to the joint would be potentially a phalanx and its epiphysis, while the part proximal to the joint would be the distal epiphysis of the as yet distal phalanx. The simplest view is to regard the part between every two joints, or distal to the distal joint, as an element capable of becoming a bony phalanx with its unossified part, or epiphysis, at each end. In digit IV., the first mentioned cartilage represents a phalanx and its distal epiphysis; the distal cartilage, the same as the element distal to the joint in the terminal cartilage in III. and V. In digit II., in which the great expanded cartilage has two joints, the proximal part may be regarded as the distal

epiphysis of the distal bone, and the parts on either side of the
distal joint as potentially a phalanx and its two epiphyses.
Possessing the cartilaginous elements above indicated, ossifica-
tion might thus give additional phalanges as follows, to digit
II., 2; to digits III. and V., 1; to digit IV., 2.

10. THE BONES OF THE DIGITS—*Relative Length of the Digits.*
—Referring to Table III., it is seen that digit III. is the longest,
as in B. musculus, but that digit IV. comes rather nearer to it
in length than in B. musculus. Also that digits II. and V.
are short relatively to digits III. and IV., being under half the
length, while in B. musculus they attain to about two-thirds of
the length of the two long digits. In Megaptera the radial
digit II., the index, contrasts greatly with the ulnar digit V.,
in the robustness and length of its bones compared with those
of B. musculus. With a phalanx less than digit V. it maintains
its greater length; its three bones are not far from twice the
length of the corresponding bones of digit V., and are several
times their thickness, while in B. musculus the difference in
length and in the thickness of the bones of these two digits
is not great. The enormous robustness in particular of the
metacarpal bone of the radial digit in Megaptera almost reminds
one of the metatarsal of the human hallux, having the same
adaptation, giving resistance to that side of the limb.

Number of the Digital Bones.—The number of the bones,
including the metacarpal, in each of the four digits, is,—digit
II., 3; digit III., 8; digit IV., 7 (and a cartilage); digit V., 4.
Beyond these, each digit has the terminal cartilage, those of
digits V. and III. with a joint in 'them, that of digit II. with
two successive joints in it.

The following Table, giving the number of ossified bones,
including the metacarpal, found in each finger in my four
dissections of B. musculus (all males), shows how the number
may vary according to maturity or otherwise. The Table does
not give the terminal cartilages, which might subsequently have
become ossified. The number in the B. borealis (male), also
given in the Table, is the same as in the 50-feet-long B. mus-
culus.

11. TABLE III.—*Number of Ossified Bones in each Digit.*

	II.	III.	IV.	V.
Balænoptera musculus, 65–66 feet long, . . .	5	8	8	5
,, ,, 60½ feet long, . . .	5	7	6	4
,, ,, 64 feet long, . . .	4	7	6	4
,, ,, 50 feet long, . . .	4	7	6	4
Balænoptera borealis, 35 feet long, ...	4	7	6	4
Megaptera longimana, 40 feet long,[1]	3	8	7	4

In the 60½-feet-long B. musculus, digit III. is somewhat deformed, the three distal bones detached, narrow, and partly pushed up between digits III. and IV. The 5th bone of its digit II. is a very narrow cone about an inch in length. This whale was mature if not aged. Its pisiform cartilage is partly ossified. In the 65 to 66-feet-long B. musculus, which may be regarded as aged, the 5th bone of digit II. is 2¼ inches in length; the 5th bone (now lost) of digit V. was 2½ inches in length. The 8th bone of digit IV. is small, ⅝ inch in length. I have no note as to the presence of a terminal cartilage in addition to the 5, 8, 8, 5 bones. In the 64-feet-long B. musculus each digit had a terminal cartilage, in addition to the 4, 7, 6, 4 bones (this *Journal*, 1871).

Looking to the state of the terminal cartilages above described, it would appear that this Megaptera has unossified cartilages in

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[1] The number of bones in each digit of Megaptera given by Van Beneden and Gervais (*Ostéographie des Cétacés*, completed 1877, Pl. X. and XI., fig. 5, the Megaptera longimana of the Brussels Museum ; Text, p. 129) is, including the metacarpal, 3, 8, 8, 4 ; beyond these a terminal cartilage is figured, though not of the same shape as in my Megaptera. The number figured by D'Alton, in his fasciculus (*Die Skelete der Cetaceen*, 1827, Taf. III., fig. *e*), is 3, 8, 7, 3, with what appears to be intended for a terminal cartilage on each. The form of the phalanges is not well represented. In the small figure given by Rudolphi of the skeleton of his 43-feet-long Megaptera longimana (*Loc. cit.*, Taf. I., fig. 1) the numbers shown, including the metacarpals, are 3, 9, 7, 4 ; but he mentions that the 9th of digit III. "hat keine Knochensubstanz." The number given by Eschricht (*Loc. cit.*, p. 141) is 3, 9, 9, 3. His figures are from two fœtuses. In that from his 45-inch-long fœtus (Taf. III., fig. 4) his enumeration, 3, 8, 8, 3, is in addition to the metacarpal bones. The terminal pieces in the figure would correspond numerically to what I have described above as the terminal cartilage, except in his digit V. which would require an additional piece. In his figure (XVIII. p. 79) of the 35-inch-long fœtus, if the metacarpal and the terminal cartilage are included, the numbers are, 4, 10, 10, 4. In my Megaptera the inclusion of the metacarpal and the terminal cartilage would make the numbers 4, 9, 9, 5 ; or in view of the two joints in the terminal cartilage of the index, 5, 9, 9, 5.

digits II. and V., which bring their number up to that of the ossified bones in the mature B. musculus, and unossified cartilages in digits III. and IV., which would, if ossified, bring their number up to 9 each. Megaptera, therefore, has at most, if at all, one more phalanx in its two long digits than B. musculus. The great length of the second digit in *Globicephalus melas* (Digit I., 4 bones; II., 14; III., 9; IV., 3; V., 1) is obtained by increasing the number of the bones, but Megaptera, true to its affinities, gains the great length of its two long digits by elongation of the bones.

12. TABLE IV., *showing, in inches, the Length of the Digits and the Length, Breadth and Thickness of the Bones in each. Farther Cartilages are indicated by the letter C.*

	Megaptera longimana.				B. musculus, 50 feet long.[1]			
	I.	III.	IV.	V.	II.	III.	IV.	V.
Total length from carpus to tip of distal cartilage,	38	▮	60	32½	17¼	25½	23	15¼
1st bone (Metacarpal), length,	9	12	9	5¼	3¾	5	4¼	3½
„ „ breadth,	4½	2¾	2	2½	1½	1¾	1½	1¾
„ „ thickness,	3½	2½	1½	1¼	1¼	1¼		
2nd bone „ length,	10	11¼	9¼	5¾	3¼	4½	4	3
„ „ breadth,	2¾	2½	1⅝	1¾		1½	1½	▮
„ „ thickness,	2¼	2½	1½					
3rd bone „ length,	7½	9½	9	4¾	3¼	3½	3¼	2¼
„ „ breadth,	1⅜	2⅞	1½	I		▮	1	
„ „ thickness,	1⅜	2⅜	1⅜					
4th bone „ length,	C	7⅝	7⅝	▮	2	2½	2¼	1⅜
„ „ breadth,	...	2⅜	1⅜		⅞	1		
„ „ thickness,	...	1⅜	1⅜					
5th bone „ length,	C	6	5⅜	C	C?	▮	1⅜	C?
„ „ breadth,	...	2¼	1⅜	..	...	▮		...
„ „ thickness,	...	1⅜	1	...	...			...
6th bone „ length,	...	4⅝	3⅜	...	...	1⅜	▮	...
„ „ breadth,	...	▮	1⅜	...	...			...
„ „ thickness,	...	▮	⅜	...	...	...		...
7th bone „ length,	...	3	2¼	...	...	×	C?	...
„ „ breadth,	...	1½	1	...	...	...	...	...
„ „ thickness,	...			...	...	...	...	..
8th bone „ length,	...	▮	C	...	...	C?	C?	...
„ „ breadth,	...	▮	...	...	...	...	...	...
„ „ thickness,	...		...	...	...	...	...	...
9th segment (cartilage),	...	C	C	..	...	...	...	...
The bones together, length,	26¼	55½	46½	17¾	12¾	17⅝	16⅜	10¼
Leaving for the cartilages,	11¾	25¾	33⅞	14⅜	4⅝	7⅜	6¼	4⅜
Proportion of cartilage to the entire digit, per cent.,	33	31·9	42·3	45	27·5	29·9	▮	31·1

[1] In this B. musculus the state of the terminal cartilages could not be ascer-

Relative Length of the Digital Bones.—Running the eye down the columns of Table IV. it is seen that, in B. musculus, the lengths diminish gradually from the metacarpal onwards in the two long digits. But in Megaptera the first phalanx is longer than the metacarpal in all the digits except digit III., although its first phalanx is the longest of the first phalanges. This is owing to the still greater excess in length of the meta-carpal of digit III., the metacarpal and first phalanx of which together exceed in length by 4⅝ inches the two corresponding bones of digit IV., although the total length of digit III. exceeds that of digit IV. by only one inch. In digit II. of the 50-feet-long B. musculus the first phalanx is slightly longer than the metacarpal, and in my more mature specimens of B. musculus it is so in the case of both digits II. and V., in the 65 to 66-feet-long specimen to the extent of from ½ to ¾ inch, but they present no other exception to the progressive diminution in length onwards. The exceptionally great length of the metacarpal and first phalanx of digit III. in Megaptera, will be referred to in connection with the adaptation of the nodes and hollows of neighbouring digits.

Form of the Digital Bones.—In my more mature specimens of *B. musculus* the ends of the bones are concave towards the nodes, especially from side to side, most marked at the first two nodes of digit III. and the first node of digit IV., but most marked at the first node of digit III. On the lateral digits the bones are rather cut obliquely, so as to give a somewhat wedge-shaped node, the base of the wedge towards the free margin.

tained. The 7th bone of its digit III. was injured. In Table III. it is seen that in the most mature B. musculus digits II. and V. had 5 bones each, digits III. and IV. 8 bones each. In this Table, IV., the lengths are taken along the middle; the breadth and thickness at the middle of the shafts, where the bones are narrowest. The breadth is from radial to ulnar, the thickness from flexor to extensor aspect. To show the much greater breadth at the ends of each bone than at the middle, I subjoin the following measurements, in inches, of the breadths of each bone of digit III. of Megaptera, at its distal and proximal ends, that of the proximal end placed first :—1st bone, 4⅝, 4¾ ; 2nd bone, 4½, 5 ; 3rd bone, 5¼, 5₁₋₆ ; 4th bone, 4⅝, 4⅝ ; 5th bone, 3⅝, 4₁₋₆ ; 6th bone, 3₁₋₆, 3¼; 7th bone, 2¼, 2⅝ ; 8th bone, 1½, 1⅔. It is seen from these measurements that, with the exception of the metacarpal, and slightly of the second phalanx, the expansion is greater at the distal than at the proximal end. This is seen, and to a more marked degree, on all the bones of digit IV. It does not apply, however, to the 1st and 3rd bones of digit II., or to the 1st and 2nd bones of digit V.

The measurements of these bones were all made along the middle to avoid fallacy arising from these variously shaped ends. In the *Megaptera* there is very little of the cupping at the ends, though it is discernible at the first nodes of digits II., III., and IV. But the oblique cutting of the ends in digits II. and V., giving the wedge-shaped node, is distinct, and the same is seen on digits III. and IV. after they have passed beyond the lateral digits, the base of the wedge towards the free border of each. This wedge form of the node must tend to give the digits more lateral movement from the axis of the limb, as in spreading the fingers.

In all the specimens of *B. musculus* the finger bones have the hour-glass form. The expansion at the ends is less on the metacarpals, owing to the greater breadth of the shafts, and is least at the carpal end of the two middle digits. The hour-glass form is less marked on the three distal phalanges of the long fingers and on the two distal of the shorter fingers, as the phalanges become more flattened. Roughly speaking, the expanded ends are about twice the breadth of the shaft, at the middle. The above applies to *Megaptera* also with the following peculiarities. In digit II. the metacarpal presents less expansion owing to the great robustness of its shaft, but its other two bones have the most hour-glass form of all the finger bones. The excavation of their shaft accommodates the first and second nodes of digit III., but is no less marked on their free border, owing to the great expansion at their ends to support the large nodes which project on their free border. The excavation on the ulnar side of the first phalanx of digit II. to receive the first node of digit III., flattens the border so much as to give the shaft a prismatic form. A like excavation and flattening is seen on the much smaller corresponding bone in B. musculus. The bones of digit IV. appear slender in the series in Megaptera compared with B. musculus, owing not only to the great robustness of digit III. but likewise to that of digit II. But comparing simply the two long digits in Megaptera and in B. musculus, the difference in the robustness of the two digits is striking,

Breadth and Thickness of the Digital Bones.—The measurements given in Table IV., showing the breadth and thickness of

each bone in Megaptera and in the 50-feet-long B. musculus, give interesting results, read across and read down each column. Reading across, it is seen that, in both of these whales, both the breadth and thickness of the metacarpal bones, and of the corresponding range of phalanges, diminish progressively from digit III. to digit V., with the single exception of the metacarpal of digit V. which is ⅓ inch broader than that of digit IV. In B. musculus the metacarpal of digit II. is likewise ⅓ inch broader than that of digit III., and they are of the same thickness. In Megaptera the metacarpal of digit II. is seen to be greatly more robust than that of digit III., exceeding it in breadth by a half, in thickness by about a fifth.

Reading down the columns, it is seen that, in *B. musculus*, both the breadth and the thickness diminish progressively onwards, the only exception being that in digit III. its 2nd and 3rd bones have the same thickness, and its 3rd and 4th bones the same breadth. In *Megaptera* the exceptions to progressive diminution distally are in digit III., that the 3rd bone is the broadest (⅜ inch broader than the 2nd, and 1 inch broader than the metacarpal) and that the 4th bone has the same breadth as the 2nd; in digit IV., that the 2nd and 3rd bones have the same thickness, and the 3rd and 4th bones the same breadth.

Comparing the breadth with the thickness, irrespective of size, reading across each range, it is seen *in B. musculus*, that, from radial to ulnar side of the paddle, there is a proportionate diminution of the thickness, giving a progressive flattening of form from digit II. to digit V.; less marked from digit II. to digit III., well-marked at digit IV., and very marked at digit V.; and it is seen to be more marked as we read down the columns. The only exception is on the metacarpal bone of digit III., the thickness of which is only ⅓ inch less than the breadth, while it is ⅔ less on the metacarpal of digit II. In *Megaptera* there is not the same progressive flattening from the radial to the ulnar side of the paddle. Reading across the range, the bones that are thickest in proportion to their breadth are the 2nd of digit II., the 1st of digit III., and the 4th and 5th of digit IV. The bones of digit V. have a more flattened form than the others in the range, but their length compared with their breadth renders this less striking to the eye.

Reading down the columns, comparing the breadth with the thickness of each bone, the flattening goes on progressively, *in B. musculus*, in all, becoming more and more marked. It is but little on the metacarpal bone of digit III., and on digit II. after the metacarpal. In my 65 to 66-feet-long B. musculus, as in Megaptera, the thickness of the 2nd bone of digit II. is greater than the breadth, the shaft being excavated to make room for the first node of digit III., but no other bone in digit II. of that B. musculus is thicker than it is broad. In *Megaptera*, the 2nd bone of digit II. is thicker than broad, owing to the adaptation above mentioned, and these two measurements are equal in the 2nd bone of digit III., and in the 3rd bone of digit IV. The metacarpals of digits III. and IV. in B. musculus are a little thicker in proportion to their breadth than the first phalanx is, which is not the case in Megaptera. Comparing digits III. and IV. of Megaptera, the first two bones of digit III. are thicker in proportion to their breadth than those of digit IV., but this proportion is reversed on the 3rd, 4th, 5th, and 6th bones of these two digits. Hence the more slender appearance of the bones of digit IV. in proportion to their length, viewed along the surface.

Viewing the digital bones of *Megaptera*, these measurements show that there is a variable proportion between the robustness and the length. In digit II. the metacarpal has the same length as that of digit IV. but it is twice as robust. Its 2nd bone also, and to some extent its 3rd, are more robust, in proportion to their length, than the corresponding bones of digit IV. All along digits III. and IV., the greater robustness of the bones of the former, in proportion to their length, is striking. In digit III. the third bone is actually more robust than the 2nd, and it is $1\frac{3}{4}$ inch shorter. Its remaining phalanges also are more robust than the 2nd bone, in proportion to their length. This is after digit III. has ceased to be splinted on its radial side by digit II. In like manner in digit IV., the 2nd bone is not so robust, in proportion to its length, as the bones beyond it, but this is not to so marked an extent on the immediately succeeding bone as in digit III. In digit V., however, the 3rd and 4th bones are not more robust in proportion to their length than the 2nd bone.

13. PROPORTION OF CARTILAGE TO BONE IN THE FINGERS.—
The extent to which each finger is formed of bone and of cartilage
in these two whales is seen in Table IV. In the B. musculus
(50-feet-long) the proportions are to be taken as approximative
only, as in a more mature state the distal cartilages would be
in part ossified. But the proportions in my 64-feet-long B.
musculus correspond pretty well, being, of bone and cartilage,
respectively, in digit II., 18⅔ and 6⅓ inches; digit III., 25 and
8½; digit IV., 22¼ and 8½; and in digit V., 14 and 5. The
comparison is most reliable on the two long digits. In the
Megaptera, the great terminal cartilage gives digit II. a large
percentage of cartilage, but in all its digits the percentage of
cartilage is greater than in B. musculus, although the latter (50-
feet-long) is probably not more mature. The high percentage
of cartilage in digit IV. of Megaptera is to some extent gained
by the 8th element not being ossified, but is mainly owing to
the relative shortness of the more distal bones of the digit.
It would appear, therefore, that the great length of the fingers
in Megaptera, compared with those of B. musculus, while
mainly obtained by bone, is in still larger proportion gained by
cartilage. This should allow of greater flexibility, but may be
regarded rather as related to the greater robustness of the bones
in Megaptera. The large amount of cartilage in the fingers
of the cetacea, reaching in these two whales to about from $\frac{3}{10}$
to $\frac{4}{10}$ of the whole length of the digit, may be regarded as an
adaptation to general flexibility in digits so ensheathed that
their constituent bones cannot be moved separately.

14. ADAPTATIONS OF THE NODES AND PHALANGES TO EACH
OTHER IN NEIGHBOURING FINGERS.—The alternating nodes and
hollows fit into each other more closely than would appear
from the skeleton. The nodes are very large, most prominent
at the middle where they project ½ to ¾ inch on each side
beyond the level of the expanded ends of the bones. On the
surfaces, flexor and extensor, the nodes do not rise above the
level of the enlarged ends of the bones, except to form a gentle
convexity. The great enlargement is in the breadth. Stated
generally, the nodes are about three times as broad as the narrow
part of the phalanges at the middle of the shaft. The bones
and the nodes, both invested in their thick fibrous covering, form

a series of alternating great elevations and hollows, continued smoothly from one to the other, and mostly fitted to each other. The nodes are not generally opposite the middle of the hollows. That could only well be with equal length of the bones of neighbouring digits. The hollows are about twice the length of the nodes, and the node may be received into the proximal, or the middle, or the distal part of the hollow.

The alternation is accomplished simply thus. By the greater length of the metacarpal bone and also of the first phalanx of digit III. the nodes of that digit are projected just beyond the nodes of the two neighbouring digits, which, again, are about opposite each other. The result is that the nodes of digit III. are received into the proximal part of the hollow of the succeeding phalanx of the neighbouring digits, and that the nodes of the latter are received into the distal part of the hollow of the corresponding bone of digit III. Then, by the shortness of the metacarpal of digit V., the adaptations between it and digit IV. are in like manner accomplished. If digits II. to V. of the human hand be placed together, it will be seen that there is the same arrangement of the phalanges in them, more evident if the observer will imagine the middle finger drawn forward a little. In these other fin-whales the method by which the nodes are rendered not opposite each other is the same, but the result is less striking in them than in Megaptera, owing to the comparative shortness of the bones and to the lesser size of the node compared with the breadth of the phalanges in them.

The following are the exact positions of the nodes in Megaptera. In digit III. their position opposite the proximal part of the hollow of the succeeding bone continues till the next last node, the 6th, is reached, which is seen to lie in the distal half of the hollow, owing to the shortness of the 6th bone of digit IV. The 5th node may be said to occupy the entire hollow of the 6th bone of digit IV. In digit IV., correspondingly, the fitting of the nodes against the distal part of the hollows of digit III., is continued on the first five; the 6th lies in the whole hollow, and the 7th more on the proximal side of the hollow. Of digit II. the first node lies in the distal third of the hollow of the metacarpal, the second just past the middle

of the hollow of the 2nd bone of digit III. The expanded terminal cartilage of digit II. is opposite the proximal part of the hollow of the 2nd bone of digit III. but not close to it. The 2nd bone of digit II. receives the first node of digit III. at the proximal half, and is so excavated by it that the breadth of this shaft is less than its thickness. The 3rd bone of digit II. receives the 2nd node of digit III. at the distal half of its hollow. Digit V. has so short a metacarpal bone, and begins so much earlier at the carpus, that its first node lies even proximal to the middle of the metacarpal of digit IV. The second node is nearly opposite the first node of digit IV., its centre about an inch beyond the centre of the latter, but the node is very flat on the side next digit IV., and prominent on the free border. The 3rd node is opposite, but not close to, the distal part of the hollow of the 2nd bone of digit IV., and is very prominent on that side, but not on the free border. The hollow just beyond it corresponds to the 2nd node of digit IV. But digit V. is not in close relation with digit IV., though its metacarpal bone is not so divergent as that of digit V. is in the other finners.

Almost all the nodes which are on the free borders project more, and also rise to a sharper point, like mountain peaks, on the side next the free border. Exceptions to this were in the 3rd node of digit V. which, however, was 1½ inch from contact, and in the 3rd node of digit III., the one succeeding the great terminal projection of digit II. For the most part the nodes in relation with neighbouring digits lie pretty close to them, the intervening spaces occupied by fatty and other soft tissues. Digits III. and IV. were only about ¼ inch from actual contact with each other at the 4th and 5th nodes of each. At other parts the interdigital space is wider, 1 to 2 or even 2¾ inches. Between digits II. and III. the space averages an inch, increasing distally. Digit V., after its 2nd node, is not near digit IV. At the tip, digits III. and IV. are not close together, about 2½ inches apart. Digit III. projects 2 inches beyond digit IV. though it is only 1 inch longer. It begins 1 inch later at the carpus than digit IV.

It would seem not improbable that the adaptation of these alternating nodes and hollows may, from this cause alone, to

some extent determine the relative length of some of the phalanges. With digits near each other the nodes must lie in some part of the neighbouring hollows. That the joints should not be on a line with each other in the paddle is a farther reason for difference in the length of the phalanges. Had they been in a line with each other, transversely or obliquely, the paddle would have been liable to bend or break at the line.[1]

15. MUSCLES OF THE FINGERS AND FORE-ARM.—Considering the great size of the pectoral fin in Megaptera longimana, it was interesting to ascertain whether finger-muscles are present, and if present, whether they are more developed than in other finners, or still more rudimentary.[2] By incisions I was allowed to make in the fore-arm, when the Megaptera was on exhibition at Aberdeen in February 1884, I satisfied myself that red muscles were present, and I was able to dissect them fully in the autumn of that year. I found the same muscles present as in B. musculus, but instead of being larger, like the fingers on which they act, they were not half the size of those of

[1] It may be well to mention the means taken to secure accuracy in regard to these and other points in the anatomy of the paddle, besides the measurements. (1) An exact paper shape was cut of the entire paddle when attached to the carcase. (2) After the skin, fat, &c., had been removed in the dissecting-room, an outline of each digit was carefully traced on paper, showing the size and relations of the nodes and phalanges. (3) Before the bones were macerated, saw marks were placed on the proximal end of the flexor aspect of each, such as to enable us to articulate every bone in its right place.

[2] The presence of muscles in the fore-arm of a cetacean was first noticed by Professor Flower, C. B. (in *B.musculus, Proc. Zool. Soc.*, 1865). They were described in *B. rostrata* by Drs Carte and Macalister (*Trans. Roy. Soc.*, 1868), and by Mr J. B. Perrin (*Proc. Zool. Soc.*, 1870). By the author, in this *Journal*, fully, in *B. musculus* (1871); in a toothed cetacean, *Hyperoodon bidens* (1871 and 1873); in the Greenland Right-Whale, *Balæna mysticetus* (1878); and in this whale, *Megaptera longimana*, in a preliminary note, at the meeting of the American Association for the Advancement of Science, at Philadelphia, in September 1884 (*American Naturalist*, February 1885). By Dr John Anderson, in *Platanista gangetica* (*Anat. and Zool. Researches*, 1878). By Sir William Turner, in Sowerby's Whale, *Mesoplodon bidens* (this *Journal*, 1885), with which he gives an account of his dissection of them in a fœtus of B. Sibbaldii, made in 1869–70. In the Narwhal, *Monodon monoceros;* the White Whale, *Beluga; Globicephalus melas;* and in the common Porpoise, *Phocœna*, I found these muscles to be present morphologically, but histologically represented by fibrous tissue, being functionally ligaments. But in *Phocœna*, the flexor carpi ulnaris was present in the fleshy condition. (This *Journal*, 1871, 1877, and at the Aberdeen Meeting of the British Association for the Advancement of Science, 1885.)

B. musculus. They were, on the internal aspect, three,—a flexor digitorum ulnaris, a flexor digitorum radialis, and the flexor carpi ulnaris; on the external aspect, one, an extensor communis digitorum. The proportions of the two flexors of the fingers were reversed, as compared with those of B. musculus, the ulnar flexor being about a third the size of the radial flexor, instead of larger than it, as in B. musculus.

The account of these muscles in Megaptera may be shortened by referring to the figures which I gave of them in B. musculus, which are here reproduced in Plate XI. figs. 13 and 14; and reference may be made to my detailed account of the muscles in B. musculus (this *Journal*, 1871). It was a mature B. musculus, 64 feet long, the pectoral fin 7 feet 8 inches long, the longest digit 33½ inches in length; while in this Megaptera the pectoral fin was 12 feet long, the longest digit 81 inches in length.

Flexor carpi ulnaris.—Belly does not spread like a fan as it does in B. musculus, but is thick and fusiform from the origin onwards. Origin entirely on the cartilaginous olecranon, abruptly from its distal edge, the aponeurosis reaching for about ½ inch forwards. Fleshy for 11 inches, being nearly half the length. Thickness of flesh at origin fully 1 inch, at middle ¾ inch. Belly covered by a thick aponeurosis of origin. Tendon of reception is continued on deep aspect of belly. Length of fleshy bundles about 1 inch, running obliquely between the two aponeuroses. The tendon, after 4 inches from the belly, is elliptical in section, lies edgeways to the ulna, is 1½ inch from the ulna, the total distance here from the ulna to the free upper border of the paddle, 6 inches. Tendon lies in a strong sheath, which also covers the belly, distinct from the aponeurosis of origin, and goes down to the upper border of the ulna. This is the strong fibrous curtain which I noted in B. mysticetus, absent in B. musculus. The blubber between the tendon and the free border of the paddle is much mixed with fibrous tissue, in longitudinal streaks. Distally the tendon gradually gets nearer the ulna, narrowing the fibrous curtain, expands in the last 3 inches, and is inserted entirely into the proximal border of the pisiform cartilage, not reaching quite up to the angle of the pisiform. The tendon at 4 inches from the flesh

was nearly as bulky as the common tendon of the two flexors. The flexor carpi ulnaris is, therefore, as far as I could judge, as fully developed in Megaptera as in B. musculus, relatively to the flexors of the digits more so. It will serve to give increased resistance to this soft part of the paddle.

Flexor digitorum ulnaris.—This muscle resembles the same muscle in B. musculus, but is very much smaller. Belly, length 5 inches, flesh continued 1 inch farther on deep aspect of tendon ; greatest breadth, at middle, 1½ inch; thickness, ¼ to ½ inch; figure triangular. Origin from the ulna, doubtful if any fibres come so far forwards as from the humerus. Belly lies obliquely on the slope to the interosseous space. Tendon 14 inches before it joins tendon of radial flexor. Lies on interosseous slope of ulna and then for 5 or 6 inches sunk in the interosseous space, finally getting into same sheath as radial flexor. Tendon is about ½ inch broad, and about twice the bulk of that of an average human plantaris muscle.

Flexor digitorum radialis.—Is about three times the size of the last muscle, but smaller than in B. musculus. Arises from the ulna as well as from the radius, beginning about 4 inches later than the ulnar flexor, length of belly 8 inches, the flesh running on the deep aspect of the tendon for 3 or 4 inches more. The tendon runs up in the belly like a septum, rendering it bipenniform, as in B. musculus. Bulk of belly about that of two thick fingers. Tendon, after 4 inches of pure tendon, in all 16 inches from the origin of the muscle, receives the tendon of the last muscle. This is at about the junction of the middle and distal thirds of the fore-arm. Tendon lies deep in the interosseous hollow, flattened sideways, about ½ inch thick.

Dissection.—Each of these muscles lies in a sheath of fibrous tissue, ¼ to ½ inch thick. The fleshy fibres partly arise from this sheath. The tendons are not very loose within the sheath, as if they did not move far. From their interosseous position and the great thickness of the sheaths these tendons and fleshy parts too, might readily be overlooked. The first structure come on, on slitting up the very thick aponeurosis of the fore-arm, on the flexor aspect, is a great nerve, as large as the forefinger, surrounded by loose areolar tissue within its sheath. Also in a

sheath, along the radial border of the interosseous space, is a large artery, continued along the radial border of the common tendon.

Common Tendon.—The tendons of the two flexors unite in a common triangular expansion, the bulk of which appears to exceed that of the two tendons which form it. From this four tendons proceed, of about equal size, to the four digits. Breadth of the tendons along proximal half of the digits, 1 to 1½ inch; on distal half broader, on the cartilages 2 inches. They go to the ends of the digits. They have a fibrous covering, but not regularly formed thecae and have no synovial covering, only areolar tissue between. Their function must be ligamentous, with traction exerted on them by the muscles.

The greater size of the radial flexor than of the ulnar flexor in Megaptera, in contrast with their proportions in B. musculus, is interesting as in adaptation to the greater size of digit II. in Megaptera. Although the two tendons unite in a common expansion, the radial flexor will exert its traction on the radial side.

Extensor communis digitorum.—Fleshy belly 18 inches in length, greatest breadth 1½ inch, being same length as in B. musculus, but only half the breadth. Tendon ⅝ inch in breadth in B. musculus was 1¼ inch. Is about size of human tendo Achillis. Forms large triangular expansion on distal half of carpus, which gives off four tendons at the proximal ends of the metacarpal bones. The division in B. musculus was earlier, at about the middle of the carpus. Tendon to digit III. the largest, that to digit V. the smallest. At middle of digit III. the tendon is twice the bulk of the entire tendon in the fore-arm; breadth 2 inches, thickness ¼ inch. The tendons have attachments to all the bones and joints.

Here, then, we see in the great paddle of Megaptera the same muscles not half the size they have in the much smaller paddle of B. musculus, illustrating their rudimentary condition. The great increase of the bulk of the tendons on the digits is an illustration of their mainly ligamentous function. The traction exerted on them by the muscles will give some additional resistance on both aspects.

(B) The Hind Limb.

16. Table V., *showing, in inches, the Length, Breadth, and Thickness of the Pelvic Bone and the Femur in the Megaptera longimana.*

	Length.	Breadth.	Thickness.
	Inches.	Inches.	Inches.
Pelvic bone (including cartilages) straight	9¼	...	...
,, anterior portion (beak)[1]	5	...	...
,, posterior portion (body)	6½	...	...
,, ossified part	4¼	...	...
,, anterior cartilage	2	...	...
,, posterior cartilage	3¼	...	...
,, at middle of beak, right	...	1⅞	⅝
,, ,, ,, left	...	⅞	½
,, at the promontory, right	...	2½	1
,, ,, ,, left	...	2¼	1
,, at middle of body, right	...	1⅝	⅝
,, ,, ,, left	...	1¼	⅝
Femur (including ⅛-inch-thick perichondrium), right	5	...	...
,, ,, left	3¾	...	...
,, greatest, near posterior end, right	...	1½	1⅜
,, ,, ,, left	...	1½	1
,, at middle, right	...	1⅜	⅝
,, ,, left	...	1¼	⅝
,, at ½ inch from anterior end	...	⅞	½

17. The Pelvic Bone (figs. 15 and 16, *P.*).—As seen in the preceding Table, scarcely half of the length of the pelvic bone is ossified. This contrasts remarkably with the condition of the bone in Rudolphi's 44-feet-long Megaptera (English measure), also a male. In the full-sized figure which he gives (*op. cit.*, Taf. IV.) the length of the ossified portion is fully 9 inches, while neither of the cartilages is an inch in length. It contrasts also with the condition of the bone in my 50-feet-long B. musculus, in which the lengths of the corresponding parts are, the ossified part 8½ to 9 inches, the posterior cartilage ½ inch, the anterior cartilage about 1 inch. In form, the pelvic bone contrasts with that of this B. musculus in being less flattened and in having a much less extended promontory. The breadth at the promontory in the B. musculus is 4 to 4½ inches, in the

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[1] The measurements of the anterior and posterior portions of the pelvic bone are taken from the middle of the outer border of the promontory to the tip of each.

Megaptera only 2¼ to 2½ inches. Nor is the promontory in Megaptera tipped with cartilage.

The *acetabular cartilage* which I found in the Greenland Right-Whale (*loc. cit.*, figured in Plate XIV.), and which I find to be present in my 50-feet-long B. musculus, is entirely absent in this Megaptera. On raising the periosteum carefully at the promontory and from both surfaces near it, no cartilage of any kind is seen.

18. THE FEMUR[1] (figs. 15 and 16, *F.*).—The femur is entirely cartilaginous. On horizontal section in its whole length, the cartilage is seen to be traversed by the usual large Haversian canals, in that section divided transversely, at distances of ⅛ to ¼ inch, less towards the tapering anterior end, wider apart towards the thicker posterior end. It is closely embraced by its perichondrial capsule, averaging ⅛ inch in thickness, thinner behind thicker in front. The difference in length between the right (3¾ inches) and the left (5¼ inches, the cartilage proper 5 inches) is striking. The form is that of a pine-cone, a little flattened, so that the surfaces are inferior and superior, the borders internal and external. In Eschricht's figure of the fœtal cartilage, it has a somewhat pear-shape, with a pinched anterior third; in the adult he defines the form as "fast wie die einer menschlichen Kniescheibe," but his figure of it is longer and less pointed than a human patella. In this Megaptera (as seen in fig. 16, R. and L.) it presents two slight lateral projections on both borders with a constriction between. The projections are seen to correspond to the attachment of ligaments or other

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[1] The presence of this bone in Megaptera was discovered by Eschricht. Writing in 1840 (*loc. cit.*, p. 136) he mentions having first found it in fœtal Humpbacks, male and female, as a cartilaginous nodule. In his figure (fig. 43) of the full size in a 78-inch-long fœtus, it is somewhat under ½ inch in length, the pelvic bone 1¾ inch. He figures it (fig. 44), reduced to ¼th, from a full-grown Humpback, the pelvis of which had been sent to him from Greenland, as nearly 2 inches in length, adding the important fact that, in this "erwachsenen Thiere," "Er war hier grösstentheils verknöchert." When the presence of a rudimentary femur in B. musculus was discovered by Professor Flower, C.B. (*Proc. Zool. Soc.*, 1865), it was in the condition of a cartilage, 1¼ inch long by ¾ inch broad, although the whale was 67-feet-long and a male. In the 64-feet-long B. musculus (*loc. cit.*, 1871, and plate vii. fig. 3) I found it mostly in an ossified condition, 2 inches in length, 1¼ in breadth, ⅝ in thickness, ossified in the proximal ⅔ of its length. But in my 50-feet-long B. musculus, also a male, the femur is entirely cartilaginous, 1½ to 1⅝ inch long by 1 inch broad.

fibrous bands. It may seem stretching comparison too far, but if the forms which I figured of the femur in the Greenland Right-Whale (loc. cit., Plate XIV.) are looked at, it will be seen that these parts may be compared to the head, neck, and trochanter, the shaft represented only by the tapering anterior end.

The femur has no articular connection with the pelvic bone, joined to it only by ligaments posteriorly, 1½ inch in length, allowing it to play loosely on the pelvic bone internal to and in front of the promontory. The anterior portion (beak) of the pelvic bone for a couple of inches in front of the promontory is concave on this aspect where the femur crosses it, the beak directed forwards and inwards, the femur forwards and outwards.

19. LIGAMENTS, OTHER FIBROUS STRUCTURES, AND MUSCLES CONNECTED WITH THE PELVIC BONE AND THE FEMUR.—Space will allow me to give here only a short account of the soft parts met with in the dissection. The muscles are very different from those which I figured in the male Greenland Right-Whale (loc. cit., Plate XVI.), this in part resulting from the much greater development of the femur and the presence of a rudimentary tibia in the latter. The arrangement of the soft parts in Megaptera corresponds pretty closely to that in B. musculus, an account of which, with more complete illustrations, I hope to publish soon. Meanwhile I give the figures (figs. 15 and 16) showing the arrangement in Megaptera, and if these figures be referred to the following short notes of these parts may be understood. These figures are reduced to ⅛th, from full-sized drawings which I made as the dissection proceeded. The chief point of interest was to ascertain to what extent function could explain the presence of so very rudimentary a structure as this representation of the femur in Megaptera.

Posterior Connections of the Pelvic Bone.—Passing across between the posterior ends of the pelvic bones is the *great interpelvic ligament* (a.a., figs. 15 and 16). Attached for 1½ inch to the bone, and about ½ inch thick. It ties the pelvic bones together posteriorly, and supports the crura penis, which are involved in its tissue anteriorly, and entirely rest on it. Behind, it attaches the anterior part of the *levator ani muscle* (b, fig. 15), and more externally the inner part of the caudal

muscular mass (c.). Along the posterior edge of the great
ligament is seen the posterior edge of the *transversus perinei
muscle* (d.) mostly concealed by and attached to the ligament;
as broad and as thick as the palm of the hand and 6 to 8 inches
in length transversely. In the ring between this muscle and
the beginning of the levator ani muscle, is seen the *retractor
penis muscle* (e.e,), rope-like, right and left, passing forwards on
the under surface of the penis; composed of pale unstriped
muscular fibre, as in other cetaceans. On the great transverse
ligament and crus penis is seen the *ischio-cavernosus muscle*
(f.f.). This great muscle, 10 to 14 inches in length, 5 to 6
inches in breadth, and 3 inches in thickness at the middle,
extends still more on the dorsal aspect than on the under
aspect where it is seen in the figure; when split long-ways at
the middle, I estimated each half as equal in bulk to an average
human gluteus maximus. It has no direct connection with the
pelvic bone, its bundles passing entirely between the interpelvic
ligament, crura and corpora cavernosa penis. It is considerably
more developed, especially in breadth, in Megaptera than in
B. musculus. It and the last muscle are very much more
developed in Mysticetus, forming what I described and figured
(*loc. cit.*, figs. 13 and 14, *l.* and *m.*) as the great compressor
muscle and the posterior compressor muscle. The references
to the muscles of the hind limb in B. musculus are from my
dissection of the 50-feet-long one.

At the posterior part of the pelvic bone is the *posterior or
caudal muscular mass* (g.), as seen in section 2 inches behind
the bone, at least 6 inches broad by 3 inches thick. Backwards,
it begins to unite with its fellow in a median raphé after a course
of 18 inches, just behind the anus. Forwards, it is attached
internally to the outer part of the great interpelvic ligament
(c.), but mainly to the pelvic bone, to the end and for 3 inches
on the outer side by fleshy attachment, on the outer border and
both surfaces. Besides these attachments it sends forwards a
tendinous sheet worthy of particular notice. The outer part of
this sheet skirts the pelvic bone externally, and runs into the
anterior muscular (or tendinous) mass of the beak of the pelvic
bone; its middle and inner parts after covering and thus
strapping down the pelvic bone, pass, the middle part to be

attached to the outer edge of the femur, the inner part to form a fibrous sheet covering and adhering to the superficial surface of the femur. These latter parts, all however forming a continuous sheet, thus strap down the femur, and enable the caudal mass to act in part as a retractor of the femur, tightening it backwards and also outwards. This backward connection of the femur is strengthened by a deeper fibrous stratum, passing back from the femur to the pelvic bone and to the outer part of the great interpelvic ligament. Near the femur these posterior fibrous connections are $\frac{1}{3}$ to $\frac{1}{2}$ inch thick, farther back the deeper stratum is about $\frac{1}{8}$ inch thick. The latter will serve purely as a ligament.

Anterior Connections of the Pelvic Bone.—The arrangement of the *anterior or trunk muscular mass* in Megaptera differs from that in B. musculus and still more from that in Mysticetus. In the latter, in a 33-feet-long *Mysticetus*, a great mass of flesh, 10 inches by 3 inches, came back to be attached, fleshy, to the beak, to the long nearly parallel femur, and to the tibia, separating into internal and external parts. In the *B. musculus* also there was a very large fleshy mass here, about 9 inches by 6, but most of it attached only to a great fibrous septum, to which also is attached a portion of the posterior caudal mass. To the anterior half of the beak was directly attached a mass of flesh 4 inches by 1 inch, and separately at the outer part, just in front of the promontory, a tendon, $1\frac{1}{2}$ inch broad, which after a course of $1\frac{1}{2}$ inch gave off a large lateral anterior muscle. In *Megaptera* this latter, $1\frac{1}{4}$ inch in breadth here, strengthened by a part arising on the outer side of the promontory, is the only structure I saw attached to the beak of the pelvic bone (fig. 15, *i.i.*). It was fibrous for 4 inches forwards, and was joined on its outer side by the part of the tendinous prolongation of the posterior caudal mass above noticed as skirting the pelvic bone externally. In connection with this difference in the soft parts attached to the beak in these two species of finners, is to be remarked the shortness of the beak, compared with the body of the pelvic bone, in Megaptera. Measured from the middle of the outer edge of the promontory, the lengths of the beak and the body are, respectively, in the 50-feet-long B. musculus 9 inches and $5\frac{1}{2}$

inches; in the 64-feet-long B. musculus, 14½ inches and 11 inches; while in this Megaptera the beak is 5 to 5½, the body 6¼ inches.

The Superficial Interpelvic and Interfemoral Aponeurosis. —This great sheet of fibrous tissue is seen (fig. 15, *k.k.*) to pass across superficially between the pelvic bones and neighbouring parts, connecting them together, and supporting the parts of the penis. Breadth, antero-posteriorly, fully 12 inches, extending forwards in front of the pelvis to the transverse superficial muscle which exists there, and backwards to the beginning of the posterior third of the pelvic bone. Here it ends rapidly in a curved line with a median peak. If this edge is not natural the membrane is at least very thin from here back to the levator ani muscle, this space appearing after dissection as a perineal window through which the parts at the root of the penis are seen. This interpelvic aponeurosis may be regarded as a part of the general transverse aponeurosis of the region, specially thickened and attached where it lies between the pelvic bones and thigh bones. Thickness at the middle line, about ¼ inch, the part opposite the femur and fore part of the pelvic bone, ½ inch. Its lateral connections at the pelvis are in three strata; the deepest attached to the pelvic bone; the middle, passing through between the pelvic bone and the femur, and blending with the deep tendinous tissue prolonged from the caudal mass; the superficial stratum, attached to the inner edge and superficial aspect of the femur, blending with its perichondrium. Behind the femur the aponeurosis joins the posterior fibrous connections of that bone; anteriorly it passes on the deep aspect of the anterior fibrous connections of the femur, to reach the inner edge of the anterior third of that bone and the deep longitudinal tendinous tissue, but it is not attached to the very apex of the femur or to the prolongation band, going across above these, and leaving them as more superficial parts. This great aponeurosis is composed of coarse transverse bundles of white fibrous tissue mixed with areolar tissue and fat. It was only after repeated examination with the microscope that I was satisfied it was nowhere muscular. In dissecting not very fresh cetacean tissues, streaks of brown-coloured blubber are sometimes extremely like muscle to the naked eye.

The Deep Ligaments and Retractor Muscle of the Femur.
—The *posterior ligament* (figs. 15 and 16, *l.*), much the
largest, resembles the letter Y reversed. Attached to posterior
end of femur, undivided part 1½ inch long, as broad as forefinger
but not so thick. External division flattened, ¾ to 1 inch broad,
directed backwards and a little outwards, 1 to 1½ inch long, at-
tached to pelvic bone about 2½ inches from femur. Internal divi-
sion conical form, slopes backwards and inwards for 3 to 4 inches,
attached to great interpelvic ligament and crus penis by a 2-inch-
broad base, beginning 1 to 1½ inch internal to the pelvic bone.

On cutting into this limb of the posterior ligament, it is
seen to be hollow and to contain a muscle, composed of red
striped fibre. This *retractor femoris muscle* (fig. 16, right
side, *r.m.*) is from 2¼ to 3 inches in length; in breadth, at the
base 1¼ to 2 inches, at the middle 1 inch; thickness at the base
about 1 inch. The enclosing sheath (the ligament) is 1/10 inch
thick. The chief origin of the muscle is, for its outer half, from
the interpelvic ligament, and for its inner half from the ¼ to
½-inch-thick fibrous wall of the crus penis. There it comes in
close relation with fibres of the ischio-cavernosus muscle, but
the two muscles diverge immediately. Part of the bundles
arise from the inner surface of the sheath at its base, and are
inserted into the sheath farther forwards, especially towards
the apex, the central part ending in a short tendon which soon
becomes identified with the central part of this limb of the liga-
ment. The above applies to the ligament and muscle of the
right side, that on which the femur is largest. On the left side,
the internal limb of the ligament and the contained muscle are
much less developed. This muscle will pull the femur back-
wards and a little inwards, while the enclosing sheath will serve
as a ligament checking forward movement. Considered in
relation to the size of the bone on which it acts, this is a large
muscle, having a bulk of flesh say equal to the thumb modelled
into a cone. The posterior ligament is the great one in all these
cetacea possessing a femur, but I have not found in B. mus-
culus or in Mysticetus anything corresponding to the inner
limb of the ligament and its contained muscle.

External Ligament of the Femur (fig. 15, *m.*).—A flattened
triangular band, 1½ inch long, attachments towards promontory

and outer side of head of femur; at middle ¾ inch broad, ₁/₁₀ inch thick, but about half that size on left side. Its pelvic attachment is at what would be the acetabular cartilage in Mysticetus, and in B. musculus. There is an elevation of the bone here in Megaptera, but rather to the inside of where the acetabular cartilage is in these other whales. The ligament is attached at the outer side of this elevation on the left side, at its inner on the right. On the left side the ligament, directed inward and forward, will check gliding movement of the femur in these directions. On the right side, owing also to the more outward position of the femur, the ligament turns round the outer edge and goes on to the outer part of the superficial surface of the femur, and is so placed that it checks gliding movement in the outward direction, and rotation inwards. On the left side an intermediate ligament, stronger than the external ligament, is seen, associated more with the posterior ligament than with the external. Not present on right side.

The Anterior Fibrous Connections of the Femur.—The great anterior band of the femur is attached not only to the apex, but by thinner continuations to each side of the anterior third of the femur, as far as the anterior lateral tuberosity (fig. 15, *n.*, right side). In the figure, on the left side, these continuations are removed, bringing into view (fig. 15, *o.*) a band which arose from the deep surface of the femur, opposite to that tuberosity, ¾ inch broad, flattened but a thick strong band, stronger on the right side than on the left. It is a deeper stratum of the fibrous tissue at the outer part of the great anterior band, separated, seemingly, by its being connected externally with the fibrous prolongation from the caudal mass, a portion of which is seen joining it in the figure.

The great anterior band may be termed the *femoral prolongation band*, regarding it as representing a continuation of the femur, like the tibial band which appears to represent a continuation of the tibia in Mysticetus (*loc. cit.*, fig. 18, *k.*). Arising at and near the apex of the femur, it has a size of 1¾ inch broad by ¼ to ½ inch thick, oval in section, thicker internally than externally; passes forwards for about 15 inches, expanding, and ends by joining the fibrous tissue at the posterior part of the large superficial transverse muscle, which there supports the

prepuce on the anterior half of the penis. Although not noted during the dissection, the edges, I think, were joined by, or gave off, a fibrous expansion, but the band stood out prominently as a long flat tendon-like structure, and, as above noted, lay superficial to the great transverse interpelvic aponeurosis.

Summary of the Connections of the Femur.—(a) The *purely fibrous* connections are, *posteriorly*, the deep posterior ligament to the pelvic bone; and superficial to it, the fibrous stratum to the pelvic bone and interpelvic ligament. These will offer strong resistance to over-advancement of the femur. *Anteriorly*, the prolongation band. The anterior attachment of this band not being to bone, the resistance offered by it to retraction will not be very definite. *Internally*, to its fellow, by the great transverse aponeurosis. This will offer strong resistance to outward movement. *Externally*, the external lateral ligament to the pelvic bone; and the adhesion of the longitudinal tendinous tissue on the outer side of the pelvic bone. (b) *Muscular influences.*—From the caudal muscular mass, by those parts of its anterior tendinous prolongation which are attached to the hinder end and outer border of the femur. Will tend to pull the femur backwards and a little outwards when the pelvic bone is being retracted. The special retractor muscle, which will pull the femur backwards and a little inwards, when a tight condition of the interpelvic ligament and crus penis gives the muscle a fixed point to pull from. The only muscular action on the femur, therefore, appears to be retraction, and the chief ligamentous resistance is against advancement.

Exact Position of the Femur.—On the right side, that of the larger femur, about the posterior half of the femur lies on the pelvic bone. On the left side, the like decussation of the axes of the beak and of the femur, leaves but the apex of the femur in front of the beak. The right femur lies in the general hollow of the beak, with their periosteum and loose tissue between. On the left side, in addition, the middle stratum of the transverse aponeurosis was noted as lying between, the left femur being placed somewhat more internally than the right, as represented in the figure. Now, in the ligamentous preparation, the parts being quite loose, it looks as if the left femur had lain in the same position as the right, allowing for its being shorter. The

laxity of the ligamentous connections of the femur in Megaptera, compared with those of Mysticetus and B. musculus, is striking.

20. FUNCTION.—The more the connections of the femur in Megaptera are examined the less easy does it seem to give a functional explanation of its presence. It might be looked on as serving a sesamoid function, but it does not play on cartilage, and does not give the mechanical advantages of a sesamoid. It has even less muscular connection than the small oval femur in my 50-feet-long B. musculus. Mysticetus has also a rudimentary tibia, Megaptera a femur only, B. musculus a still more rudimentary femur, and B. borealis, as I find, none at all.

21. EXPLANATION OF PLATES X., XI., and XII.

Fig. 6. Left paddle of Megaptera, flexor aspect, reduced to $\frac{1}{2\frac{1}{4}}$. The epiphyses of the humerus and fore-arm are seen. The epiphyses of the fore-arm and metacarpal bones, at the carpus, are to be distinguished from the carpus bones proper. The causes of the nine nodes on the radial border, shown in Part I., Plate V., are seen ; and of the minor undulations on the ulnar border, near the tip. The fitting of the alternating nodes and hollows of the digits, the position of the joint in the nodes, and of the joints in the terminal cartilages, are represented.

Fig. 7. Left scapula of Megaptera, turned round to show the dorsal surface, with its very lów spine, *s.* *a,* anterior angle ; *p,* posterior angle ; *c,* rudimentary coracoid ; *d,* low elevation ; reduced to $\frac{1}{2\frac{1}{4}}$.

Fig. 8. View of glenoid cavity of same scapula. *c,* rudimentary coracoid, not yet completely united to the scapula.

Fig. 9. Dorsal view of section of left carpus of Megaptera with portions of radius and ulna and their epiphyses, and portions of the metacarpal bones and the epiphysis of each ; reduced to $\frac{1}{12}$.   *r,* radiale ; *i,* intermedium ; *u,* ulnare ; *p,* pisiform ; *3,* os magnum ; *4,* unciform bone. Ossification is seen in the radiale and ulnare, and in the epiphysis of the radius and of the ulna. These ossifications are seen only on section. The dotted line is where the pisiform and the epiphysis of the ulna are not completely separate. The proximal synovial cavity at the os magnum, *3,* is represented.

Fig. 10. Terminal cartilage, with distal phalanx, of digit III.; *a,* the joint in the cartilage ; reduced to $\frac{1}{2}$.

Fig. 11. Terminal cartilage, with part of distal phalanx of digit II. (Index digit). *a,* its first joint; *b,* its second joint. Reduced to $\frac{1}{2}$.

Fig. 12. Longitudinal vertical section of the terminal cartilage of digit II., showing the two joints *a* and *b* ; the proximal reaching both surfaces ; the distal seen only on section ; reduced to $\frac{1}{2}$. The flexor aspect of fig. 12 is that next to fig. 11. The radial border of figs. 10 and 11 is towards fig. 12.

Figs. 13 and 14. Pectoral fin of the 64-feet-long B. musculus, reproduced from this *Journal*, 1871, for comparison with that of Megaptera; and for the muscles, flexor and extensor. Reduced to $\frac{1}{16}$.

Fig. 15. The pelvic bone and femur and their muscular and fibrous connections in the male Megaptera longimana; reduced to $\frac{1}{4}$. The dissection carried deeper on the left side. *P*, pelvic bone; *F*, femur. The dotted line shows the position of the right pelvic bone; *a*, great interpelvic ligament, at its attachment to pelvic bone; *b*, part of levator ani muscle; *c*, part of the caudal muscular mass; *d*, transversus perinei muscle, only the posterior border seen; *e.e.*, retractor penis muscle, right and left; *f*, ischio-cavernosus muscle, lying on interpelvic ligament and crus penis. The dotted lines show its position covered by the interpelvic aponeurosis; the inner dotted line shows its line of termination on the under aspect of the corpus cavernosum penis; *g*, attachments of caudal muscular mass to pelvic bone and interpelvic ligament; *h*, prolongations of its tendon to the femur and along outer side of pelvic bone; *i.i.*, attachments of anterior muscular mass to pelvic bone, in Megaptera only by tendon; *k.k.*, great interpelvic and interfemoral aponeurosis; *l*, posterior ligament of femur, bifurcated. A portion of the internal limb is seen on the right side; *m*, external ligament of femur; *n*, femoral prolongation band. On left side the thinner lateral parts of that band removed, showing *o*, separate part attached on deep aspect of femur and joined by part of tendinous prolongation from caudal mass.

Fig. 16. Pelvic bone and femur and their ligaments reduced to $\frac{1}{4}$. The right femur is seen to be larger than the left. The letters refer to the same parts as in fig. 15; *r.m.*, on right side, retractor femoris muscle, contained in the inner limb of the posterior ligament.

(*To be continued.*)

VARIATIONS IN THE HIPPOCAMPUS MAJOR AND EMINENTIA COLLATERALIS IN THE HUMAN BRAIN.[1]

By ROBERT HOWDEN, M.B., *Demonstrator of Anatomy, University of Edinburgh.* (PLATE XIII.)

ON comparing the descending cornua of the lateral ventricles in a series of brains, one is struck with the marked differences which exist in the size and shape of the hippocampus major and eminentia collateralis. Having recently examined a number of adult brains, I propose to give a short summary of the chief variations noticed:—

I. *The Hippocampus Major.*

Its average length, measured in a straight line from the anterior extremity of the pes hippocampi to the notch between the hippocampus major and minor, is from 4 to $4\frac{1}{2}$ cm.; occasionally it reaches 5 cm., but is more frequently shortened to $3\frac{1}{2}$ cm., or even less. In the latter case it is as a rule more curved, forming the segment of a smaller circle, so that the apparent antero-posterior shortening is largely compensated for in this way.

Its average width, near its middle, from the outer convex border to the inner margin of the tænia hippocampi, is about 1 cm., but sometimes this is reduced to little more than a $\frac{1}{2}$ cm.

Its prominence in the descending cornu varies considerably— usually it forms a well-marked eminence, aptly compared to a half-bent forefinger, but in many cases it is much more flattened. Its posterior part especially is very variable in size, being sometimes large and rounded, sometimes very small and almost completely hidden by the tænia hippocampi, while frequently it is incompletely separated from the anterior part by a well-marked depression. This diminution in the size of the posterior part seems to be associated with a great development of the eminentia collateralis, and with a broad tænia (figs. 1 and 2).

Much variation is also seen in the size and shape of the pes hippocampi. Sometimes it presents a large knob-like extremity projecting outwards into the apex of the descending horn, in others it tapers gradually forwards, and ends in a more or less flattened extremity. The indentations on it vary from one to four, the more frequent number being three. Instead of being limited to the pes they sometimes extend along the outer convex surface of the hippocampus for some little distance. Tiedemann, in 1821, quoted by Rolleston (*Scientific Papers and Addresses*, vol. i. p. 29), regarded these indentations as being peculiar to man, but five years later (*Zeitsch. f. Physiologie*, 1826) he described them as being present on the brain of the orang—a fact which he had not observed on the cornu ammonis of other apes. In the dissection of the orang's brain described by Rolleston himself (vol. i. p. 19) he states " that there are several well-marked corrugations on the expanded lower extremity of the hippocampus major, but they are on its posterior, not on its anterior, surface."

The tænia hippocampi—lying along the concave surface of the hippocampus major—covers on an average its inner third. It is, however, sometimes very broad, and, as already mentioned, may completely hide from view the posterior part of the hippocampus, which, as a rule in such cases, is much smaller than usual.

The dentate convolution or dentate fascia (?) lies, as a rule, deeply in the hippocampal fissure, and can scarcely at all be seen until the tænia is raised. In many cases it is found almost completely exposed beyond the inner edge of the tænia, and can then be readily recognised without disturbing the latter. This condition is not, as one might perhaps expect, best seen where the tænia is narrow, but is associated rather with a broad tænia and a narrow hippocampus; in other words, it is associated with a shallow hippocampal fissure. The grey matter of the dentate convolution forms a flattened lamina, notched on its inner edge and varying considerably in width—being sometimes barely visible, while at others it shows a width of over ½ cm In one instance it consisted of a tongue-like process projecting inwards for nearly 1 cm. beyond the margin of the tænia hippocampi (fig. 2).

II. The Eminentia Collateralis.

This is described as a "smooth eminence at the junction of the posterior, with the descending horn between the hippocampus major and minor, which may extend some way down the descending horn behind the great hippocampus" (Quain's Anatomy, 9th ed., vol. ii. p. 346). It presents, however, marked variations in size and form, the following being the chief :—

1. Instead of forming an eminence it frequently assumes the condition of a triangular depression, occupying a much lower level than either hippocampus, and showing merely a slight convexity on its upper surface (fig. 3).

2. Sometimes it comes to project so as to be almost on a level with the posterior part of the hippocampus major, still, however, retaining its limited triangular form.

3. The most important variation is where it extends forwards and downwards, as a well-marked eminence, into the descending horn, lying to the outer side of the hippocampus major. When this forward extension occurs it may show three chief varieties :—

(a) It may gradually fade off into the outer wall of the descending horn at a point opposite the middle of the hippocampus major.

(b) It may run forwards and downwards as a large eminence —varying from ½ to 1 cm. in width—parallel with and to the outer side of the hippocampus major, and curving inwards in front of the pes hippocampi it ends in a blunt rounded extremity. In those cases it frequently rises to a higher level in the floor of the ventricle than the hippocampus itself, and may measure as much as 6½ cm. in length (figs. 1 and 2).

(c) In some instances this anterior extension is incompletely separated by a shallow depression from the more or less triangular posterior part; when this exists a condition is seen which somewhat resembles that figured by Schwalbe (Lehrbuch der Neurologie, fig. 321, p. 509), who names the posterior part "Trigonum ventriculi" and the anterior part "pes accessorius."

Accompanying this large and elongated condition of the collateral eminence, there is generally found considerable narrowing of the hippocampus major, this being most marked at its posterior part, as already mentioned.

On examining the tentorial surfaces of these specimens, one finds, as might be expected, that in those cases where the hippocampus major is small and the dentate convolution well exposed, there is usually a shallow hippocampal fissure, especially at its posterior part.

The collateral fissure, generally well marked on the tentorial surface, varies within moderate limits both as regards length and depth. Its average length is from 7 to 9 cm., while sometimes it is elongated to 10 or 11 cm., and only occasionally it is shortened to 6 cm. Its average depth is from 1 to 1½ cm. Its anterior extremity extends usually to within a short distance of the apex of the temporo-sphenoidal lobe, while posteriorly it frequently bifurcates, one limb running directly backwards towards the tip of the occipital lobe, while the other, much shorter, inclines upwards towards the calcarine fissure, although as a rule not becoming continuous with it.

One is struck with the great average length of this fissure as compared with that of the corresponding eminentia produced in the lateral ventricle, and is naturally inclined to ask:—How is it that the collateral fissure is, as a rule, so long, while the resulting eminentia is so variable in size and frequently so small ? The answer depends, I think, on the following factors :—

1. On the width of the hippocampal convolution, especially at its anterior part, near where it becomes continuous with the uncus. This varies from ½ cm. to 1½ cm., with the result that where the convolution is broad the anterior part of the collateral fissure necessarily occupies a position more external on the tentorial surface of the hemisphere, and thus the indentation produced by it, in such cases, is not seen on the floor of the descending horn.

2. A bridging convolution sometimes stretches across the anterior part of the fissure, connecting the inferior temporo-occipital and hippocampal convolutions. When this annectant gyrus is present it breaks the continuity of the collateral fissure, so that it is now represented by an elongated posterior part, which makes its mark in the ventricle, and by an anterior shorter portion which is not deep enough to produce an elevation in the descending horn. This is also associated with a diminution in the transverse diameter of the descending horn, so that the outer convex edge of the hippocampus major is in close proxi-

mity to the outer wall of that horn. Sometimes this "bridging" convolution stretches across the bottom of an otherwise deep fissure, and can only be seen on opening up the fissure. This gives rise to the shallow depression, already mentioned as sometimes crossing and partially dividing the elongated eminentia.

3. On the depth of the fissure, and more especially on the degree of obliquity in the direction which it follows on being traced from the surface into the brain substance. One naturally expects that a deep collateral fissure will produce a correspondingly large eminentia, and such, within certain limits, is the case, but I think that too much value may be placed on mere depth, and not enough on the direction of the plane of the fissure as it dips inwards from the brain surface. For example, the average depth of the fissure is from 1 to 1½ cm., and this is tolerably constant, not only where the eminentia collateralis is large and prominent, but also where it is small and depressed. If, however, one introduces the handle of a scalpel into the fissure and presses gently on it, taking care to keep the instrument exactly in the plane of the fissure, it will be noticed that in those cases where the eminentia is elongated and prominent the handle of the scalpel is directed more or less vertically upwards from the tentorial surface, while in other cases, where the fissure may be quite as deep, it will be found to pass very obliquely outwards, so that if it were prolonged onwards it would be directed, not to the floor of the descending horn, but towards the brain substance external to that horn. This obliquity depends to some extent on the depth of the hippocampal fissure. If that fissure is deep two conditions follow, viz.:—(1) There is a large hippocampal eminence filling up the descending horn. (2) The collateral fissure is forced to pass more obliquely outwards. If, however, the hippocampal fissure is shallow the opposite effects are produced, i.e., a small hippocampus major, which does not occupy the whole width of the descending horn, but leaves room for a forward prolongation of the collateral eminence, while the collateral fissure is allowed to pass more vertically into the brain substance so as to be directed towards the floor of the descending horn. On making transverse sections of the descending horn, the relation of the collateral fissure to its floor is well seen. Figs. 4 and 5 represent

two such sections made across the middle of the hippocampus major. Fig. 4 is that of a specimen in which there existed a large forward prolongation of the collateral eminence (similar to that seen in fig. 1), lying to the outer side of the hippocampus major, and it shows the more or less vertical direction of the collateral fissure immediately subjacent to it. Fig. 5 is a transverse section where the collateral eminence was small, and limited to the triangular space between the hippocampus major and minor, it shows the oblique direction outwards of the collateral fissure, its summit not pointing to the floor of the descending horn, but towards the brain substance external to it.

It is not my intention in this paper to refer to the hippocampus minor and posterior horn, except to say that great variations in the size of the former and in the length of the latter were seen in the specimens examined. I would merely draw attention to fig. 3, from a specimen with an exceedingly well-marked hippocampus minor, and would add that such a condition is often associated with a small and depressed collateral eminence.

For the discussions which took place regarding the supposed value of the hippocampus minor and posterior horn in distinguishing the brain of man from that of the ape, I refer to the articles by Sir R. Owen (*Jour. Linnæan Soc. London*, 1857), Huxley, Rolleston and Marshall (*Nat. Hist. Review*, 1861).

For the beautiful drawings with which I am able to illustrate this paper I am indebted to Dr Kenneth M. Scott, clinical assistant to Dr Argyll Robertson in the Royal Infirmary.

I also exhibit a few gelatine casts of the more interesting specimens observed. These have been made after the method described by Dr C. W. Cathcart,[1] but at the suggestion of Sir William Turner I added arsenious acid in the proportion of two grains for every ounce of gelatine, the object being to insure the better preservation of the gelatine.

DESCRIPTION OF PLATE XIII.

The same letters are employed in all the figures. *H. maj.*, hippocampus major; *H. min.*, hippocampus minor; *D. C.*, dentate convolution; *T. H.*, tænia hippocampi; *E. C.*, eminentia collateralis; *C. F.*, collateral fissure.

[1] *Brit. Med. Jour.*, October 8, 1887.

ON THE ARTERIES FORMING THE CIRCLE OF WILLIS.[1] By Bertram C. A. Windle, M.A., M.D. (Dubl.), *Professor of Anatomy in the Queen's College, Birmingham.*

So far as I am aware, no attempt has been hitherto made to classify the abnormalities and variations of the larger cerebral arteries, as the result of observations made on anything like an extensive scale. Quain, in his otherwise exhaustive work, devotes but a very short space to these vessels, and other authors have followed his example. I have been for some time collecting statistics on this subject, and published a few years ago a preliminary note,[2] in which the conditions met with in sixty-five cases were described. The number of those of which I have information now amounts to 200, and the results obtained seem now to be worthy of record. I have examined the majority of these myself; for those which I have not seen I have to rely chiefly upon the careful notes made for me by friends who have occupied the position of pathologist to the General Hospital in this town, to whom, as to my friend and assistant Dr Hogben, who has also favoured me with information, I have to express my obligations. In seventy-six of the cases, the condition which obtained was strictly that which is described in the text-books as the normal arrangement.

In forty-three, however, of those reckoned as abnormal, the only deviation was a more or less well-marked disproportion between the posterior communicating arteries of the two sides. If we disregard this condition, we may say that in 119 cases out of 200, the normal number and arrangement of the arteries was present. I shall describe the variations under the head of each of the arteries forming the circle *seriatim*; in so doing it will be impossible to avoid a certain amount of repetition.

Anterior Communicating Artery.—In 159 cases this vessel

[1] Read before the Anatomical Society of Great Britain and Ireland, Nov. 22nd, 1887.

[2] *Birmingham Medical Review*, May 1884.

was normal. The most common abnormality was that of duplicity, which condition was met with in fourteen cases. Once three communicating arteries were found. In six cases there was an attempt at duplicity, or rather an incomplete form of this abnormality, in the shape of a second communicating artery placed behind the true vessel and falling into it, a triangular intervascular space being thus enclosed. In six cases there was no true communicating artery on account of a union of anterior cerebrals replacing it, a condition described by Quain as rare, and in two other instances this condition was associated with the presence of a normal communicating artery, the connection between the anterior cerebrals thus being double. In two cases there was no true communicating artery on account of the presence of only one anterior cerebral, and in one case there was none, from the complete fusion of the two anterior cerebrals. In nine cases a median artery arose from the anterior communicating.

Anterior Cerebral Arteries.—These arteries were normal in 181 cases. In nine instances a third branch was present, which may be described under the name of *A. cerebralis anterior media.* It arose in each case from the anterior communicating artery, and passed forward in the longitudinal fissure, between its two companion branches, for about two-thirds of the length of the corpus callosum. It then divided into branches for both the opposed surfaces of the hemispheres. Quain[1] mentions as a very rare variety a case of absence of anterior cerebral artery, which he quotes from a work of Arnold's,[2] which I have been unable to consult. The place of the missing vessel was taken by slender branches forming a communication between the single anterior cerebral artery and the.internal carotid of the opposite side.

I have seen two similar cases. In both the missing vessel belonged to the right side. In one its place was, to a certain extent, supplied by fine twigs from the right middle cerebral; in the other by a thread-like branch, representing the missing vessel, which sprang from the right internal carotid. In another case, which may be regarded as an intermediate condition

[1] *Commentaries on the Arteries*, p. 510.
[2] *Bemerk. über den Bau des Rückenmark*, von Dr Friedrich Arnold, Taf. 2.

between the last and the normal, the vessel of the right side was double the size of that of the left. It is worthy of note that in Quain's case, as in the three just detailed, it was the artery of the right side which failed. In one case the two anterior cerebrals united to form a single trunk which ran as such to its termination in the longitudinal fissure, giving off branches on either side to the surfaces of the hemispheres. Lastly, it may again be mentioned that the anterior cerebrals in eight cases united for a short distance, six times replacing and twice accompanying the anterior communicating.

Posterior Cerebral Arteries.—In 173 cases these vessels were normal. The commonest variety in connection with these vessels is the derivation of one or other or both from the internal carotid instead of the basilar. In eleven cases I found the right thus derived, in nine the left, and in four both. In three cases there were two posterior cerebral arteries on the same side, once on the right, twice on the left. In each case one vessel, the smaller, was derived from the basilar, the other from the carotid; both took the course of the normal posterior cerebral, and the vessels were united by one or more small anastomosing branches. I may perhaps here mention that I once saw the third nerve divided into two portions, which afterwards reunited by a twig from the posterior cerebral artery.

Posterior Communicating Arteries.—If disparity in size be left out of consideration these vessels were normal in 175 cases. The anomalies consisted in absence of one or both vessels. That of the right side was absent in nine instances, of the left in thirteen, and both were wanting in three. A marked disparity in size is more common. In twenty-eight cases the right was much larger than the left, in fifteen the left was larger than the right. In seven cases both vessels were extremely small. Where one or both arteries were wanting, there was not always a complete want of communication between the two sides. On the contrary, in the majority of cases there was a slight anastomosis in the interpeduncular space between small twigs passing from the basilar and carotid to the base of the brain in that position.

It should be noticed that the left side suffered most, both in the cases where one artery was wanting, and in those where

one was smaller than the other. In this connection it may be remarked, firstly, that the facts show that the supply of blood to the left side of the brain is, on the whole, less complete than that to the right, which militates against a theory[1] which has been put forward to account for right-handedness by the superior nutrition of the left half of the cerebrum. Secondly, the relative frequency of absence or diminution of size of the posterior communicating artery of the left side may perhaps in some cases explain the lodging of an embolus in the left middle cerebral artery, rather than in the right.

The following instances of variations in connection with these vessels may be particularised:—

1. In this case two arteries sprang from the internal carotids in the position normally occupied by the posterior communicating. Instead, however, of joining the posterior cerebral, they passed to the under surface of the temporo-sphenoidal lobe which they supplied. A few filaments from each of these anastomosed with slender twigs from the posterior cerebrals.

2. In this case the artery of the left side behaved in a similar manner to those of the previous one. There was a very small but normally placed branch on the right side.

3 and 4. In these brains there was no artery on the left side, and a mere thread on the left.

5. The posterior communicating of the left side commenced at its carotid extremity as a trunk of nearly normal size, but by giving off numerous branches to the base of the brain, was reduced to a thread before inosculating with the posterior cerebral.

6. There was no true posterior communicating on the left side; the trunk representing it passed backwards beside the posterior cerebral, shared in its distribution, and was connected with it by a very slight anastomosis of twigs derived from both.

The following anomalies do not come under any of the previous heads.

1. Described by Quain. A large branch of the left internal carotid turned backward, and after perforating the basilar part of the sphenoid bone, joined with the basilar artery, forming in fact the anterior part of that vessel.

[1] Professor Rolleston, *Brit. Assoc.*, 1877, v. *Nature*, September 6, 1877.

2. This anomalous vessel occurred in a brain removed at a *post-mortem* examination; owing to the fact that it was not at once examined, I was unable to determine its origin. The right posterior communicating artery was absent, and the right posterior cerebral arose from the internal carotid. A vessel of unknown origin ran along the right side of the pons to the right crus, along which it coursed, and crossing the right optic tract, terminated in the right Sylvian fissure by inosculating with the middle cerebral artery. In this course it communicated with (1) right superior cerebellar artery; (2) by a branch running across the middle of the crus, with a branch from the end of the basilar, which probably represented the posterior communicating otherwise wanting; before turning into the Sylvian fissure, this vessel gave off a branch which, passing in front of the optic commissure, terminated in the anterior fissure.

OBSERVATIONS ON THE INNERVATION OF AXILLARY MUSCULAR ARCHES (*Achselbogen*) IN MAN, WITH REMARKS ON THEIR HOMOLOGY SUGGESTED BY COMPARATIVE CONSIDERATIONS.

By J. T. WILSON, M.B. Edin., *now Demonstrator of Anatomy in the University of Sydney, and lately in the University of Edinburgh.*

TENDINOUS or muscular arches crossing the axilla from their attachment to the latissimus dorsi occur, according to Krause,[1] in as many as 7 per cent. of the subjects examined. Descriptions of their connections and relations are familiar, but I have searched in vain for any record of observations on their nerve supply.

In a paper on the sternalis muscle,[2] Sir William Turner makes reference to this axillary fasciculus as, along with the sternalis and others, possible or probable relics or representatives of the panniculus carnosus of other mammals. Since that time observations by others[3] on the nerve supply of the sternalis have shown its more probable affinity with the pectoral group of muscles.

During the recent session of 1887 I have had an opportunity of making a similar inquiry into the nerve supply of the axillary slip from the latissimus, the results of which are, I think, worthy of record.

In a male subject undergoing dissection for demonstration purposes (and in which there coexisted a relatively large number of variations), it was observed that the left latissimus dorsi gave off from its upper border a fleshy slip about the size of the omohyoid muscle, at a point corresponding to the junction of its fleshy belly and tendon of insertion, where also it was crossed by many transverse tendinous fibres.

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[1] *Anatomische Varietäten*, p. 98.

[2] *Jour. of Anat. and Phys.*, vol. i. p. 252.

[3] Abraham in *Trans. Acad. Med. Ireland*, vol. i. 1883 ; Cunningham in *Jour. of Anat. and Phys.*, vol. xviii., January ; Sheppard, *ib.*, xix., April ; Wallace, *ib.*, xx., October ; Lamont, *ib.*, xxi., April.

The fasciculus passed across the inner aspect of the arm, bridging over the great vessels and nerves and the coraco-brachialis muscle, and was inserted along with, or close to, the deep lamina of the folded tendon of the pectoralis major muscle at its upper border.

A very distinct nerve branch was seen to enter the fleshy belly of the slip, and this was easily traced back to the lateral cutaneous branch (the intercosto-humeral) of the second inter-costal nerve, which in this instance was pretty large. The lateral cutaneous branch of the third intercostal nerve was also found to *pierce* the slip on its way to the inner side of the arm, but, as far as could be ascertained on careful examination, no nerve twigs from this source actually supplied the fasciculus.

After the foregoing notes were made, a careful dissection of the right axilla was undertaken, with the following results:—A muscular fasciculus, exactly similar to that above described, was found on the right side. Here also the slip was pierced (not supplied) by the lateral cutaneous branch of the third inter-costal, but the lateral cutaneous branch of the second intercostal nerve was smaller than on the left side, and gave no branch to the axillary muscle. A small nerve filament, however, similar to that supplying the fasciculus on the left side, was discovered and traced to a nerve which otherwise was distributed as a cutaneous nerve to the skin of the inner side of the arm as far as the elbow, and which was plainly the lesser internal cutaneous nerve. Finally, it was observed that this representative of the nerve of Wrisberg came off from the inner cord of the brachial plexus by a common trunk with the internal anterior thoracic nerve.

Hence such questions as these naturally occur—Do the facts recorded enable us to establish the real homology of this little axillary muscle ? Do they tend to confirm the suggestion[1] that it is a representative of the panniculus, or is it, like the sternalis, really to be affiliated to the group of shoulder muscles compris-ing the pectorals and latissimi ?

It is the latter view Professor Humphry adopts[2] when he regards " such connecting axillary bands" as results of an " imper-

[1] Turner, *loc. cit.*   [2] *Jour. Anat. and Phys.*, vol. vi. p. 819.

fect segmentation" of the pectoralis from the latissimus moiety of the "superficial brachiocephalic sheet" or stratum of the great ventro-lateral muscle. And, even more particularly, he says of such slips of muscle that they are " usually formed by an extension of the latissimus dorsi, or parts of it beneath the axilla, to the pectoral muscle and pectoral ridge of the humerus."

Yet another view of the homology of the axillary muscle is advocated by J. B. Perrin. This writer refers to it as an " aborted variety of the dorso-epitrochlearis," which, in turn, he regards as an " aborted specimen of the panniculus," or a " representative of the dorso-humeral portion of the panniculus."

As against this last view I would cite the evidence of the fact that in animals a dorso-epitrochlear muscle very constantly coexists with, but is distinct from, the humeral part of the panniculus, and thus also in my subject there was on each side a well-marked dorso-epitrochlear muscular slip, which had nothing whatever to do with the axillary muscle described. But, further, the nerve supply of the dorso-epitrochlear is very different from that of the humeral panniculus in animals. Champneys[1] states that in the Chimpanzee the dorso-epitrochlear muscle is supplied by a branch of the musculo-spiral nerve, and so I have found it in the animals in which I have dissected it, viz., the Opossum, Kangaroo-rat, and Wallaby. But the nerve-supply of the panniculus differs from that of the dorso-epitrochlear as widely and fundamentally as do primary ventral from primary dorsal branches of nerve-roots. This is shown incidentally in a valuable paper by Dr A. M. Paterson,[2] on " The Limb Plexuses of Mammals," and is, I think, along with the other points referred to, conclusive proof of the independence of the dorso-epitrochlear muscle.

To aid in establishing the first view of the axillary muscle which I mentioned, I must recall Dr Paterson's statements about the nerve-supply of the panniculus. In describing the nerve-plexuses of the Porcupine, which he takes as his mammalian type, he refers, under the name of " lateral cutaneous nerve of the thorax," to a large branch of the brachial plexus, which is directed backwards along the side of the trunk, and gives off a considerable branch to the humeral panniculus.

[1] Jour. of Anat. and Phys., vol. vi. p. 180, note. [2] Ibid., vol. xxi., July.

The nerve itself is formed by united ventral divisions of the last cervical and first thoracic nerves, and in a special note Dr Paterson identifies it as the homologue of the nerve of Wrisberg in man, replacing it and fulfilling its functions, sensory and intercostal communicating. He also describes the internal anterior thoracic nerve in the Porcupine as a delicate branch given off from the same nerve cord (ventral branch of first thoracic), which gives off one of the roots of the "lateral cutaneous nerve of the thorax." I have dissected the last-named nerve in the Cat, Opossum, Kangaroo-rat, and Wallaby, and in each case with results quite similar to Dr Paterson's.

In the Cat the posterior cord ("inner" of Anthropotomy) gave off one head of the median, the ulnar and internal cutaneous nerves, and one nerve which divided into the "lateral cutaneous of the thorax," and internal anterior thoracic. The former supplied branches to the skin of the sides of the thorax and arm, muscular branches to the panniculus, and communicating branches to the lateral cutaneous twigs of the intercostal nerves.

In the Opossum the "lateral cutaneous nerve of the thorax" supplied the so-called pectoralis quartus, as well as the panniculus. In both Kangaroo-rat and Wallaby practically the same condition was found. In the latter I found a communication in the substance of the muscle between the lateral cutaneous nerve of the thorax and the lateral cutaneous branch of the second intercostal nerve.

In the cases of the marsupial animals dissected there was no internal anterior thoracic nerve at all, but a communicating branch in each case passed between the external anterior thoracic nerve and the "lateral cutaneous nerve of the thorax."

In no case was there any nerve of Wrisberg other than the last-named nerve.

The condition as regards nerve-supply observable upon the *right* side of my subject was thus essentially a repetition of the condition of the nerve-supply to the humeral panniculus in other animals, *i.e.*, a nerve of Wrisberg, given off along with an internal anterior thoracic nerve from the most posterior roots of the brachial plexus, supplied a muscle closing the axillary space, and inserted, just as is the humeral panniculus, into the pectoral ridge of the humerus.

The condition which existed on the left side may at first sight appear to present a difficulty to such an interpretation.

But when viewed in the light of Professor Cunningham's observations on the mutual relations of the nerve of Wrisberg and the intercosto-humeral nerve, the character of the variation of the two sides proves rather confirmatory than otherwise of the views here advanced. In Man, as in the typical mammalian brachial plexus of the Porcupine, the lateral cutaneous nerve of the thorax (Wrisberg's) derives fibres from the most posterior of the roots of the plexus. Cunningham has made us familiar with the inverse ratio, in respect of size, which is occasionally noticeable between the nerve of Wrisberg and the intercosto-humeral nerve in man; in other words, he has pointed out the apparent indifference with which a number of fibres of the second intercostal nerve-root pursue one or other of the two paths constituted respectively by the nerve-trunks just named.

From a more speculative point of view we may surmise that the intercosto-humeral nerve constitutes the older of the two paths indicated. Prior to any differentiation of limbs, metamerism doubtless governed the whole nerve supply of the ventro-lateral muscle, after the type of Amphioxus; and even yet it must be remembered that the lateral cutaneous branches of intercostal nerves aid the lateral cutaneous nerve of the thorax in supplying the panniculus. Indeed, it may be said that the specialisation of the latter nerve is correlated with a specialisation of the *humeral* part of the panniculus, during the progressive differentiation of the fore-limb.

But sufficient evidence has, I think, been adduced to show clearly—(1) That the axillary muscle (Achselbogen) is quite distinct from and independent of the dorso-epitrochlear muscle; (2) that it is not derived by a process of imperfect segmentation from the stratum of muscular tissue, of which the pectoralis and latissimus dorsi muscles are segments; and (3), that it is simply the representative of the humeral portion of the panniculus carnosus.

Note.—Passing reference was made to the fact that the " pectoralis quartus" in the Opossum was also supplied by the " lateral cutaneous nerve of the thorax." This is a thin

superficial muscle which arises from the abdominal aponeurosis posterior to the sternum, and is in close relation with the panniculus, and inserted along with it.

The fact of the similarity in its nerve-supply to that of the panniculus certainly seems to indicate a homology to part of the latter, when taken along with its superficial origin and insertion with the panniculus.

But when we remember the relation of the " lateral cutaneous nerve of the thorax" to the external anterior thoracic nerve, a distinct communication invariably existing between them, and the fact that in the Opossum there is no internal anterior thoracic nerve as such, we must decide to suspend judgment until a special inquiry into the homology of this muscle has been made.

SYDNEY, N.S.W.,
Nov. 11, 1887.

THE PINEAL BODY (*Epiphysis Cerebri*) IN THE BRAINS OF THE WALRUS AND SEALS.[1] By Prof. Sir WILLIAM TURNER, M.B., LL.D., F.R.S.

IT is well known that in the human brain the pineal body is scarcely so large as a common pea, its average length being from 8 to 10 mm., and its breadth about 6 or 7 mm. It does not project behind the anterior pair of tubercles of the corpora quadrigemina, and it is completely concealed by the corpus callosum and hemispheres of the cerebrum. This body possesses corresponding relations and magnitude in the brains of mammals generally, though, as M. Chauveau has shown,[2] it may occasionally assume in the brain of the horse larger dimensions, and project backwards so as to touch, or almost touch, the cerebellum.

I have found in the brain of the walrus a remarkable exception to the usual size and relations of the pineal body, as seen in the mammalian brain. In one brain, from a well-grown animal, but not an adult, the epiphysis cerebri was 30 mm. (1·18 inch) long, and 18 mm. (0·7 inch) in its greatest transverse diameter. The cerebrum itself was 121 mm. (4·7 inches) long, by 142 mm. (5·6 inches) in its greatest transverse diameter. In another brain, from a younger animal, the epiphysis was 29 mm. long, by 13 mm. in its greatest breadth, and 13 mm. in diameter, at its highest point. In both brains it was somewhat pyriform in shape, with the apex directed forwards to the optic thalami, to which it was attached; whilst the base, which was free, projected backwards so as to be visible, when the brain was looked at from above, in the mesial longitudinal fissure between the two cerebral hemispheres, where they diverged from each other posteriorly. It possessed three surfaces. One was inferior, and rested in almost its whole length on that surface of the middle lobe of the cerebellum which was in relation with the tentorium, and this surface was somewhat depressed below the level of the corresponding surface of the hemispheres of the

[1] Read to the Royal Society of Edinburgh, December 19, 1887.

[2] *Traité d'Anatomie comparée des animaux domestiques*, 1857, p. 650, fig. 177.

cerebellum, for its lodgment. The other two surfaces were lateral, and in relation to the inner and posterior border of the cerebral hemispheres, between which it was placed. These surfaces were slightly concave in their anterior two-thirds, so as to be adapted to the convex borders of the hemispheres; but more posteriorly, where the pineal body projected between the hemispheres, they were somewhat convex and mounted upwards to form a ridge in the inter-hemispherical interval. The pineal body was separated by the tentorium from the cerebrum, and was closely tied down to the cerebellum by the arachnoid and the pia mater; so close indeed was this relation, that in the first brain of the walrus, which I dissected as far back as 1865, I mistook the pineal body for a special thickening of the pia mater covering the middle lobe of the cerebellum. The apex of the epiphysis passed forwards in front of the cerebellum, and superficial to the corpora quadrigemina, to the region of the optic thalami, but, owing to this part of the brain being somewhat friable from imperfect preservation, I could not ascertain its exact connections, though there can, I think, be little doubt that, as in other mammals, it was attached to the thalami by a pair of peduncles.

The discovery of so large a pineal body in the brain of the walrus naturally made me desirous to ascertain its condition in the allied animals—the seals. In the brain of the common seal, *Phoca vitalina*, I found that it was three-sided in shape and with the apex forwards. It projected behind the corpus callosum, and rested on the corpora quadrigemina and the anterior part of the middle lobe of the cerebellum, but it did not appear between the two hemispheres of the cerebrum, when the brain was looked at from above, until the two hemispheres were drawn asunder; though its two lateral surfaces were in relation with the sides of these hemispheres for a limited distance. It was 16 mm. long, 8 mm. in greatest breadth, and 6 mm. in its greatest height. The cerebrum in this seal was 78 mm. (3 inches) in antero-posterior diameter.

In the brain of a young elephant seal, *Macrorhinus leoninus*, brought home by the naturalists of H.M.S. "Challenger,"[1]

[1] The brain of this animal is described in my Report on the Seals collected by H.MŞ. "Challenger."

the pineal body was 17 mm. long, 9 mm. in greatest breadth, and 6 mm. in greatest height. It had the same three-sided pyramidal form as in *Phoca*, and possessed similar relations to the cerebrum and cerebellum. Dr James Murie, who is, I think, the only anatomist who has systematically described [1] the brain of an eared seal, states that in *Otaria jubata* the pineal body is "relatively large," but he does not give its actual dimensions. It would appear, therefore, that in the seals the epiphysis cerebri, though undoubtedly larger than is the rule in mammals generally, is yet about only one-half as big as the same body in the walrus, and does not project so far back as to appear between the two hemispheres of the cerebrum.

The very remarkable size of this body in the brain of the walrus, and its unusual development also in the brain of the seals, are of especial interest in connection with the extremely important observations on the presence of a pineal eye in the Lacertilia, published, as the result of independent research, by H. W. de Graaf [2] and W. Baldwin Spencer [3] during the year 1886. By these naturalists the mesial foramen in the parietal bone in this group of reptiles has been seen to be occupied by an eye, and Mr Spencer has worked out in a number of species of lizards the structure of this eye and its connections, from which it would appear that the pineal eye is connected by an elongated stalk or peduncle with the thalamencephalon. This peduncle grows out of the optic thalami; at first it passes upwards in the interval between the cerebral hemispheres and the optic lobes, and then runs forwards on the dorsal aspect of the cerebrum, to end in the mesial eye, situated in the parietal foramen.

In the mammalia this apparatus has practically disappeared, and is represented only by the aborted structure which we call the pineal body. But in the seals to some extent, and in the walrus in a more remarkable manner, the pineal body has retained a greater magnitude than is customary in mammals. The direction, however, which this body takes in these mam-

[1] *Trans. Zool. Soc. Lond.*, vol. viii. part ix.
[2] *Zool. Anzeiger*, March 29, 1886.
[3] *Quart. Jour. Mic. Sci.*, October 1886.

malia is different from that of the stalk of the pineal eye in the lizards. For in these reptiles the direction of the peduncle is at first upwards and then forwards, so as not to overlie either the optic lobes or the cerebellum, whereas in the walrus and seals the direction of growth is always backwards. Two factors may operate in the cranial cavity of the walrus and seals to induce the backward direction to which I have referred, viz., the growth of the tense unyielding tentorium, and the backward development of the hemispheres of the cerebrum. Through lying subjacent to the tentorium the growth of the elongated pineal body in the direction either of the parietal bone or of the superior part of the occipital bone is effectually prevented, and the only course which it can take is towards the cerebellar region of the occiput. Similarly the posterior development of the cerebral hemispheres, which overlie both the optic lobes and the cerebellum, would by the compression of the pineal body between the cerebrum and cerebellum assist in giving it a backward direction. It is possible, also, that these same factors may operate in producing that aborted condition of this body which one finds in the mammalia as compared with the lizards. For the pressure exercised by the growth both of the tentorium and cerebral hemispheres upon an elongated structure like the pineal stalk, would occasion atrophy both of the stalk and of the pineal eye, and a consequent disappearance of the mesial parietal foramen in the mammalian skull. It is conceivable, however, that the atrophy might begin distally by bone formation closing up the parietal foramen, as a result of which both eye and stalk would disappear. But whatever cause has been in operation to lead to the disappearance of both pineal eye and stalk, only the proximal end of the pineal organ, where it arises from the thalamencephalon, is left in the mammalia. It is, however, of interest to note that in at least one mammal, viz., the walrus, this proximal end may retain such magnitude as to be visible between the hinder end of the cerebral hemispheres. But the special function, if any, which may be discharged by the pineal body in this animal will be difficult to ascertain.

ABNORMAL DISTRIBUTION OF ARTERIES AND VEINS IN THE NECK. By W. P. Mears, M.D., *Lecturer on, Examiner in, and Supervisor of, Anatomy in the Faculty of Medicine of the University of Durham.*

I HAVE just met with a modification in the vascular supply of the neck so marked as to merit—I venture to think—special notice.

The subject was an adult male; the variation occurred on the right side of the neck, and the vessels concerned were branches of the subclavian artery with the corresponding veins. The carotids and their branches—except for a high division of the common carotid,—were unaffected; the subclavian artery itself, with the jugular and subclavian veins, were in their normal positions.

1. Arising from the upper edge of the subclavian artery, three-eighths of an inch from its. origin, by a funnel-shaped root three-eighths of an inch long and a quarter of an inch wide at the mouth, was a slender pervious vessel not more than a twentieth of an inch in diameter. This vessel—ascending beneath the carotid sheath and the inferior thyroid artery,. and between the scalenus anticus and longus colli muscles—passed through from before backwards a longitudinal slit five-eighths of an inch long, in the middle cervical ganglion (the slit being bounded at either end by the halves of the body of the ganglion, and on either side by nerve bundles connecting these halves). The vessel then suddenly dipped directly backwards through an oval opening between the central part of the longus colli muscle and the lowest tendon of the upper oblique portion of that muscle, and, splitting into two divisions of equal size, disappeared between the anterior roots of the 3rd and 4th cervical transverse processes. Of its two divisions, each 1 inch long, one, impervious, joined the vertebral vein, whilst the other, pervious, opened into the vertebral artery by a funnel-shaped mouth similar to that at the origin of the vessel. The vessel was of uniform size throughout, with no sign of branches.

The thyroid axis arose 1 inch from the origin of the subclavian, from the front of that artery, immediately above the origin of the internal mammary, and in front of that of the vertebral. All these vessels were normal in size and course. The thyroid axis divided into normal inferior thyroid and suprascapular branches.

2. Between the origins of the thyroid axis and the vertebral sprung an artery half the size of the former. This vessel first ascended for half an inch, and then, curving sharply inwards and downwards under the carotid sheath, ended in two branches,—one to supply the front and right side of the trachea for the inch above its bifurcation ; the other to ramify on the longus colli in front of the 2nd and 3rd dorsal vertebræ.

3. The ascending cervical artery, much larger than usual, arose

normally, but bifurcated almost directly. One branch, the smaller, passed upwards and outwards over the scalenus anticus and the scalenus medius to end just below the mastoid process under the sterno-mastoid; the other, the larger, ran between the scalenus anticus and the longus colli muscles, entered with the 5th cervical nerve between the 4th and 5th cervical transverse processes, sent a spinal branch into the spinal canal with the 4th cervical nerve, and re-emerged at the back between the posterior roots of the 3rd and 4th cervical transverse processes under the scalenus medius (opposite the point at which the abnormal vessel (1) entered from the front). It then wound upwards and backwards under the splenius and complexus, resting first on the semispinalis and then on the rectus posticus major, to end amongst the attachments of the muscles to the skull. This branch throughout was of larger size than a normal profunda cervicis artery, which vessel was undeveloped.

4. A sixth branch of the subclavian took its origin from the back of that vessel under the scalenus anticus, five-eighths of an inch external to the thyroid axis, and appeared to be a superior intercostal artery of larger calibre than usual. It passed upwards and inwards for a quarter of an inch, then curved back to the neck of the 1st rib, and there bifurcated. One division supplied the first and second intercostal spaces in the usual way; the other ascended between the neck of the 1st rib, and the 7th cervical transverse process, curved over the semi-spinalis parallel to the corresponding branches of (3) and (5), and ended alongside the 6th cervical spine. In its course it sent twigs along the 8th cervical and 1st dorsal nerves into the spinal canal, and another larger branch between the laminæ of the 6th and 7th vertebræ.

5. A seventh branch started from the upper edge of the subclavian artery three-quarters of an inch external to the thyroid axis under the scalenus anticus, passed upwards and inwards for an inch, and then arched down *under* the scalenus medius to reach the usual position of the posterior scapular artery under the levator anguli scapulæ and rhomboidei. Half an inch from its origin this artery gave off a branch which ascended with the 7th nerve, entered with it between the 6th and 7th cervical transverse processes, sent a twig into the spinal canal with the 6th nerve, re-emerged at the back between the posterior roots of the 5th and 6th cervical transverse processes, and curved up and back to end over the semi-spinalis, parallel to, and midway between, the corresponding branches of (3) and (4).

6. The vertebral vein existed only for a fraction of an inch above and below the point where it was joined by the branch of (1). Numerous rootlets converged on it from all directions. The vein discharged itself by means of a sinus-like canal, a quarter of an inch in diameter, which passed horizontally backwards between the posterior roots of the 2nd and 3rd cervical transverse processes to end on the semi-spinalis by breaking up into similar smaller sinus-like branches among the muscles; one such branch, of crow-quill size, entered the spinal canal between the laminæ of the 2nd and 3rd

vertebrae. These sinuses when opened closely resembled hepatic veins in appearance.

On the left side there was no special abnormality noticeable, except a sinus similar in character to those on the right side, and a quarter of an inch in diameter, which was first found external to the Eustachian tube on the base of the skull, and was traced thence through the superior constrictor downwards and forwards on the deep surface of that muscle to its termination in a double blind end internal to the point of conjunction of the stylo-pharyngeus with the pharyngeal wall. The dissection was too far advanced to allow of the tracing out of its connections above.

It will be seen that in this subject the back of the neck and the spinal nerves and canal were supplied by four parallel arteries in succession from below up. The lowest (a branch of (4)) passed up over the neck of the 1st rib and back between the 7th cervical and 1st dorsal transverse processes, sending branches along the 8th cervical and 1st dorsal nerves. The next (a branch of (5)) passed up and in between the 6th and 7th processes and back between the 5th and 6th, sending branches along the 6th and 7th nerves. The next (a branch of (3)) passed up and in between the 4th and 5th processes and back between the 3rd and 4th, sending branches along the 4th and 5th nerves. Lastly, the occipital artery passed up and back over the 1st process between it and the skull, and sent a branch along the 1st nerve. All four vessels ended close to the middle line at the back. The branches of (3) and (5) passed through the vertebral canal whilst in relation with the transverse processes. • In a manner similar to the arteries the abnormal vein (6) received its root (part of (1)) between the 3rd and 4th processes anteriorly, and passed back between the 2nd and 3rd, receiving tributaries along the 3rd and 4th nerves.

(1) appeared to be a shrunken second root to the vertebral artery, having an obliterated accessory vertebral vein adherent to its surface. (2) was distributed as an accessory inferior thyroid artery.

Notices of New Books.

Lehrbuch der Anatomie der Sinnesorgane. Von G. Schwalbe, Professor der Anatomie an der Universität, Strasburg. Erlangen, 1887.

PROFESSOR SCHWALBE has now collected into a volume the three fasciculi of his important work on the Anatomy of the Organs of Sense, which were published at intervals between the years 1883–87. Like the admirable *Lehrbuch der Neurologie* by the same author, this work contains both a *résumé* of the facts collected by anatomists generally, and a number of new observations by the author himself. It is illustrated by 199 woodcuts, many of which are new, and it provides the most complete account of the structure of the elaborate apparatus associated with the senses which can be put into the hands of the student.

Translations of Foreign Biological Memoirs. Edited by J. Burdon-Sanderson, Waynflete Professor of Physiology in the University of Oxford. Oxford, 1887.

THE Clarendon Press has issued, under the editorial charge of Dr Burdon-Sanderson, a volume of translations from the German of memoirs on the Physiology of Nerve, of Muscle, and of the Electrical Organ. The first part contains memoirs by Tigerstedt, Grützner, and Hering, on researches relating to the Law of Contraction. The second part deals with researches relating to secondary Electromotive Phenomena conducted by Du Bois-Reymond, Hering, Hermann and Biedermann, whilst part 3 gives a translation of Du Bois-Reymond's papers on the electrical phenomena observed in Malapterurus and Torpedo. The translations have been made by Drs J. Niven and Aug. Waller, Messrs J. S. Haldane and Francis Gotch, Mrs Lauder Brunton, Miss Edith Prance, and the Editor. The Editor embodies in the Preface a useful analysis of the subjects of the Memoirs included in the volume, and refers to a difficulty experienced by the translators in rendering them into English, owing to the novelty of the subject as regards English scientific literature, and the difficulty frequently experienced in obtaining a proper English equivalent for many of the German expressions.

In Professor Du Bois-Reymond's memoir, on p. 374, it is stated that exact information is wanting as to how the specimens of Malapterurus, which he received from Professor Goodsir, accomplished the journey from Africa to Scotland.

The late Mr A. B. Stirling, who was for many years Goodsir's assistant, in an interesting paper, published in this *Journal,* vol. xiii. p. 350, 1879, narrates that they were brought from Old Calabar in pickle bottles, and received no further attention during the voyage than changing the water once a week, and no food was given them either during the voyage or for two weeks after their arrival in Edinburgh. The writer of this notice recollects that one specimen travelled from Old Calabar in so small a bottle that it could not swim about, or indeed lie at full length, so that the hinder part of the body and the tail were bent forward, and it was not until some time after the fish had been placed in a tank that it was able to straighten itself and move freely.

Physiologists have to thank Professor Burdon-Sanderson for having put into so accessible and readable a form the important memoirs contained in this volume.

Journal of Morphology. Edited by C. O. Whitman, with the co-operation of E. Phelps Allis, jun., No. 1, vol. i., September 1887, Boston.

WE welcome the first part of a new morphological journal from the other side of the Atlantic. It contains carefully written articles by the editor on the Germ Layers in *Clepsine ;* Professor E. B. Wilson on the Germ Bands in *Lumbricus ;* Professor Ramsay Wright and A. B. Macallum on *Sphyranura osleri ;* J. S. Kingsley on the Compound Eyes of Crangon; W. Patten on the Eyes of Molluscs and Arthropods; and G. Baur on the Phylogenetic Arrangement of the Sauropsida. The typography, illustrations, and paper are all excellent, and we wish our transatlantic sister-journal a long and prosperous career of work and usefulness.

PROCEEDINGS OF THE

ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

An Ordinary Meeting of the Society was held on Tuesday, November 22, at University College, London, at 5 p.m.—Professor Humphry, F.R.S., President, in the chair. Present—Thirty-three members and visitors.

After the minutes of the last meeting had been read and confirmed, the following gentlemen were elected members of the Society :—John Malet Purser, J. Alfred Scott, Francis Heuston, Professor Redfern, E. H. Bennett, Professor Pye, James Chambers, F. Wardrop Griffith, Campbell Williams, Percy Flemming, Edgar H. Thane, Sinclair Long, and Ambrose Birmingham. The following were then announced for election at the next meeting :—Stanley Boyd, T. E. Little, J. Torrens, and Alfred Banks.

Dr Mott then read his paper on *The Minute Anatomy of Clarke's Column of the Spinal Cord of Man, the Monkey, and the Dog*, which will be printed *in extenso* in the April number of the *Journal of Anatomy and Physiology*, vol. xxii. (N.S. vol. ii.), and was illustrated by numerous histological specimens and micro-photos of specimens.

Dr Alex. Hill was surprised at the measurements of the cells of Clarke's column given by Dr Mott, and in speaking of their development, said they appeared after those of the anterior column.

Professor Charles Stewart asked what fibres proceeded from the cells which Dr Mott had drawn.

Dr Mott replied that his method was calculated to show the exact size of the cells, and that they all had fibres.

Professor Bertram Windle then read a paper on the *Arteries at the Base of the Brain*, which paper is printed *in extenso* in the *Journal of Anatomy and Physiology*, vol. xxii. (N.S. vol. ii.), p. 289.

Mr Black spoke of a case in which the internal carotid made a complete spiral before entering the skull.

Professor Alex. Macalister mentioned cases of divided basilar artery, and said the evidence went to show that all median arteries were formed by fusion.

b

A paper by ROBERT HOWDEN, M.B, on *Variations in the Hippo-campus Major and Eminentia Collateralis* was then read. This paper was illustrated by numerous casts of brains, and drawings, and is printed *in extenso* in the *Journal of Anatomy and Physiology*, vol. xxii. (N.S. vol. ii.), p. 283.

Mr ARTHUR THOMSON wished to know whether the casts had been made before or after the brains had been hardened, and spoke of changes in shape which might ensue through the action of spirit.

Sir WILLIAM TURNER, in the absence of Mr Howden, said the moulds were obtained from hardened brains, and by means of plaster of Paris. From these moulds casts were taken with a composition of glycerine and gelatine, thickened with oxide of zinc and a small quantity of arsenious acid.

The following paper, by DAVID HEPBURN, M.B., was then read :—

A Needle in the Spinal Canal transfixing the Roots of Spinal Nerves. DAVID HEPBURN, M.B., M.R.C.S. (Eng.), Senior Demonstrator of Anatomy, University of Edinburgh.

That the tissues of the living body are to a remarkable degree tolerant of pure metals is a fact, in confirmation of which numerous illustrations can be adduced. Thus it is well known that bullets which have lodged in different parts of the human body have lain dormant for long periods without causing special annoyance to, or making their presence felt by, their possessors. Furthermore, needles which have entered the body either remain stationary, or, aided by muscular action, travel long distances from their original point of entrance, or find their way to a free surface, and so perhaps come within the reach of removal.

The late Sir James Young Simpson based his method of deligation of arteries by means of acupressure on the tolerance above referred to. As the result of his study of this subject, he formulated a theory called the " Law of Tolerance of Living Structures for the presence of Foreign Metallic Bodies." In support of this law he makes the following statement :—

"Metallic bodies when lodged and embedded without much mechanical contusion or injury in living tissues produce compara-tively little or no irritation by their presence ; and if inflammation is excited by their contact, that inflammation is usually limited to the first or adhesive stage, unless the contact at any point or points is so excessive as to produce ulceration by the mere effect of morbid pressure " (*Acupressure*, p. 457, 1864).

A curious specimen which serves still further to illustrate this tolerance, came under my notice in the Practical Anatomy Rooms of the University of Edinburgh. From the circumstances of the case it was not possible to obtain any clinical history. The subject was a female.

In the course of the dissection of the back, and as the laminæ

were being sawn through preparatory to opening the spinal canal, a piece of steel of the thickness of a sacking needle was discovered piercing the right ligamentum subflavum between the laminæ of the fourth and fifth lumbar vertebræ close to their articular processes. It did not project external to the laminæ, but, on opening the spinal canal, it was found to pierce first the trunk of a spinal nerve and then to pass through the opening in the dura mater which gave exit to this nerve.

The spinal cord and its membranes were next carefully removed from the spinal canal, and an incision made through the dura mater along its posterior aspect. This revealed the fact that the piece of metal was an inch in length, pointed and sharp at its inner end.

In its course through the *cauda equina* a number of nerve roots had been involved, some being impaled, while others were matted together by lymph of sufficient age to be firm and dense. Careful examination showed that altogether six anterior and two posterior nerve roots were so affected. These were the anterior roots of the 4th and 5th lumbar, and of the 1st, 2nd, 3rd, and 4th sacral nerves; the posterior root of the 1st lumbar (in part), and the 3rd lumbar nerve.

That part of the needle which passed amidst the nerve fibres was ensheathed in lymph, but the sharp end, half an inch in length, was free. The needle was blackened but not rusted.

The muscles of the limb supplied by the above nerves did not present any signs of atrophy when compared with those of the opposite limb.

In reply to Dr Mott,' Sir William Turner said no degeneration had been observed in the spinal cord.

Professor Struthers gave an account of his methods of preparing and preserving the brain, museum specimens, and dissections.

1. (a) *The Brain.—First Stage*, the usual process by immersion in spirit, the membranes having been removed at once in water. This may take from ten to fourteen days according to the strength of the spirit, and the frequency with which it is changed. It should not be carried too far, so as to avoid too much hardening.—*Second Stage*, let the brain lie out for a day to allow the spirit to evaporate. Then place it in the following mixture of glycerine and carbolic acid,— clear glycerine 4 parts, clear carbolic acid 1 part. He had lately used the proportion of 8 of glycerine to 1 of carbolic acid. Two or three days in this fluid will suffice. Take the brain out and allow the glycerine to drip off until only a moist state remains. The brain may now be placed under a glass shade to keep off dust. When thus prepared the convolutions are tough, flexible, and elastic, so that they may be separated down to the bottom of the sulci. The lobes and particular convolutions may then be stained with various pigments applied with a brush. To show simply the lobes, his method is to stain the temporal and parietal lobes, leaving the frontal and occipital lobes uncoloured; and in separated hemispheres to stain

of a different colour also the circumcallosal gyrus. The above method enabled the brain to be handled freely, to lie out for demonstration simply under a glass shade, or to be mounted in jars, without fluid, for the museum shelves. He had many years ago applied this process to all his series of brains, human and comparative, prepared by the old spirit process, and found it a great facility and convenience. It may be applied to brains that have been any length of time in museums in spirit. He did not think Giacomini's method (see this *Journal*, vol. xiii., 1879, p. 282) so good, unless it is wished to have the brain of almost stony hardness, like a plaster cast, not admitting of the convolutions being opened out. That was the result of Giacomini's zinc stage. He showed two brains of the sheep and two human hemispheres, prepared carefully at the same time by the two processes, as an experiment for comparison. Those by Giacomini's process were not only too much hardened, but had shrunk very much in size.

(*b*) *Moist Method for Museum Specimens.*—Inject with spirit, to which some glycerine and carbolic acid have been added, if the part admits of injection; but injection is not necessary. Saturate with the glycerine and carbolic acid mixture. But undiluted glycerine will harden too much. The proportion is glycerine 2 to 1 of water, and to 8 parts of this fluid add 1 part of carbolic acid. When glycerine is used to soften, as during dissection, the proportion should be glycerine and water equal parts. It is not necessary to immerse the part in the fluid, it may be sponged on it or otherwise applied so as to saturate. Immersion may harden too much. Then allow to drip, till only the moist condition remains. Thus prepared, the viscus or dissection is mounted in a museum jar without any fluid, simply in the moist condition and no longer dropping. It may be variously suspended within the jar, as by being fixed to a plate of glass or to a surrounding galvanised iron wire. The glass top may be cemented, or may be applied loose, retained by Goodsir's bronze ring. The advantages of this method, over that by having the jar filled with spirit, are that there is no optical distortion, that it is more economical in the end, and, if the loose cover and bronze ring are employed, that it may be conveniently taken out at any time for closer examination or demonstration. Preparations of the bladder, prostate, uterus, heart, brain (prepared specially as above), the joints, &c., and dissections of the hand, foot, &c., may be conveniently mounted thus and placed on the museum shelves. The method may be employed equally for pathological specimens.

(*c*) *Moist Method for Dissections.*—Larger dissections, as of the ligaments, muscles, blood-vessels, nerves, viscera, &c., are prepared in the above method (*b*), and are useful in teaching in addition to the recent dissections. They do not dry like spirit preparations, and may lie out in the dissecting-room or museum simply under a glass shade to keep off dust. This method may mostly supersede the spirit-basins at present fashionable in some dissecting-rooms, and by changing them from time to time, according to the stage of the

anatomical course, a great many more views may be exposed than by the basin method. Other antiseptics may be used instead of the carbolic acid, but the latter seemed to him as yet to prove the best. He was not sure, however, but that the brown colour of the dissections, after exposure to light, was greater with carbolic acid. Spirit preparations and glycerine preparations should not be placed in the same receptacle, or the spirit preparation will become mummified. To change all the dissections of the school from spirit to glycerine is attended by considerable expense, but it is economical in the end. He had managed during two autumns to overtake the whole, after being satisfied of the advantages. It would not be easy to express the improvement these changes had enabled him to effect in conducting the anatomical school. He had had the pleasure of showing the processes to various anatomical friends, and he had given this account of them to this Society in the hope that they may be tried and found useful in other anatomical schools.

Dr STRUTHERS also showed specimens of the following :—

2. (a) *Rider's bone.* Reference was made to two cases of this rare condition, viz., Mr Birkett's case (*Guy's Hosp. Reports,* 1868) and Mr Bryant's case (*Practice of Surgery,* vol. ii., 1876), in both of which the condition appeared to have had its origin in some rupture in the region of the adductor muscles during violent action on horseback. For this preparation he was indebted to his former pupil, Dr James Allan of Leeds. The dissection and notes are by Dr Allan, who had kindly consented to his bringing the preparation and case before the Society on account of the rarity of the condition. It was from a man aged 55. The bone of each side is about 1½ inch in length, ¾ to 1 inch thick, and mostly triangular. Right bone articulated to a projecting platform at the angle of the pubes, by a diarthrodial joint with very irregular surface. This bone was felt to be movable from side to side during life. Left bone immovably attached to the pubes. The muscular attachments are still seen on the left side. Adductor longus tendon directly prolonged from the end of the bone, which is flattened towards the tendon; attached to inner surface, on to the point, the fascia lata; to inner posterior border, fore part of gracilis; to outer side, inner part of pectineus; behind, a large part of adductor brevis. All these muscular attachments are of full size. But, curiously, in regard to the origin of the ossification in this case, the man would seem not to have been a rider. Dr Allan mentions that "he had been a foot soldier for twenty-one years, but I have no note of his having been much on horseback in any capacity."

(b) Series of specimens of permanently separate Acromion Process, simulating fracture.

(c) Series of preparations of the variety in which the right Subclavian Artery arises last from the arch of the aorta.

An account of these specimens will be published separately.

Professor THANE exhibited the thoracic viscera in a case of *Situs Inversus*. The subject was a male, and the transposition affected all the organs of the thorax and abdomen. As in the cases recorded by M. Weber, H. Lebonoff, and C. Aeby, there was an eparterial bronchus on the left side, but not on the right. The lungs were, however, remarkably symmetrical in their external conformation. The left lung was divided into three lobes, which were supplied by the primary branches of the bronchus in a manner precisely agreeing with the normal arrangement on the right side. The cardiac bronchus of Aeby descended from the left bronchial stem to the inner part of the lower lobe. The right lung was also divided into three lobes, in appearance like those of the left lung; but both the upper lobe and the small middle lobe were supplied by the first ventral hyparterial branch of the right bronchus. The aorta arched over the root of the right lung, and gave off its large branches in the following order, viz., left innominate, right common carotid, and right subclavian. The superior vena cava descended on the left side. and the large azygos vein passed forwards to it above the root of the left lung.

Mr ARTHUR THOMSON also showed a plan of mounting frozen sections, and Professor MACALISTER exhibited various skulls.

It was announced that the next meeting would be held at King's College in February.

Fig 2

Fig

t

t b

Fig.

b

Fig 9.

Fig 5

m m

HICUS.

2

6

1.

3

8.

4

S K I N   O F

5

9.

a

10
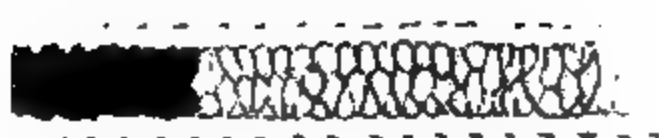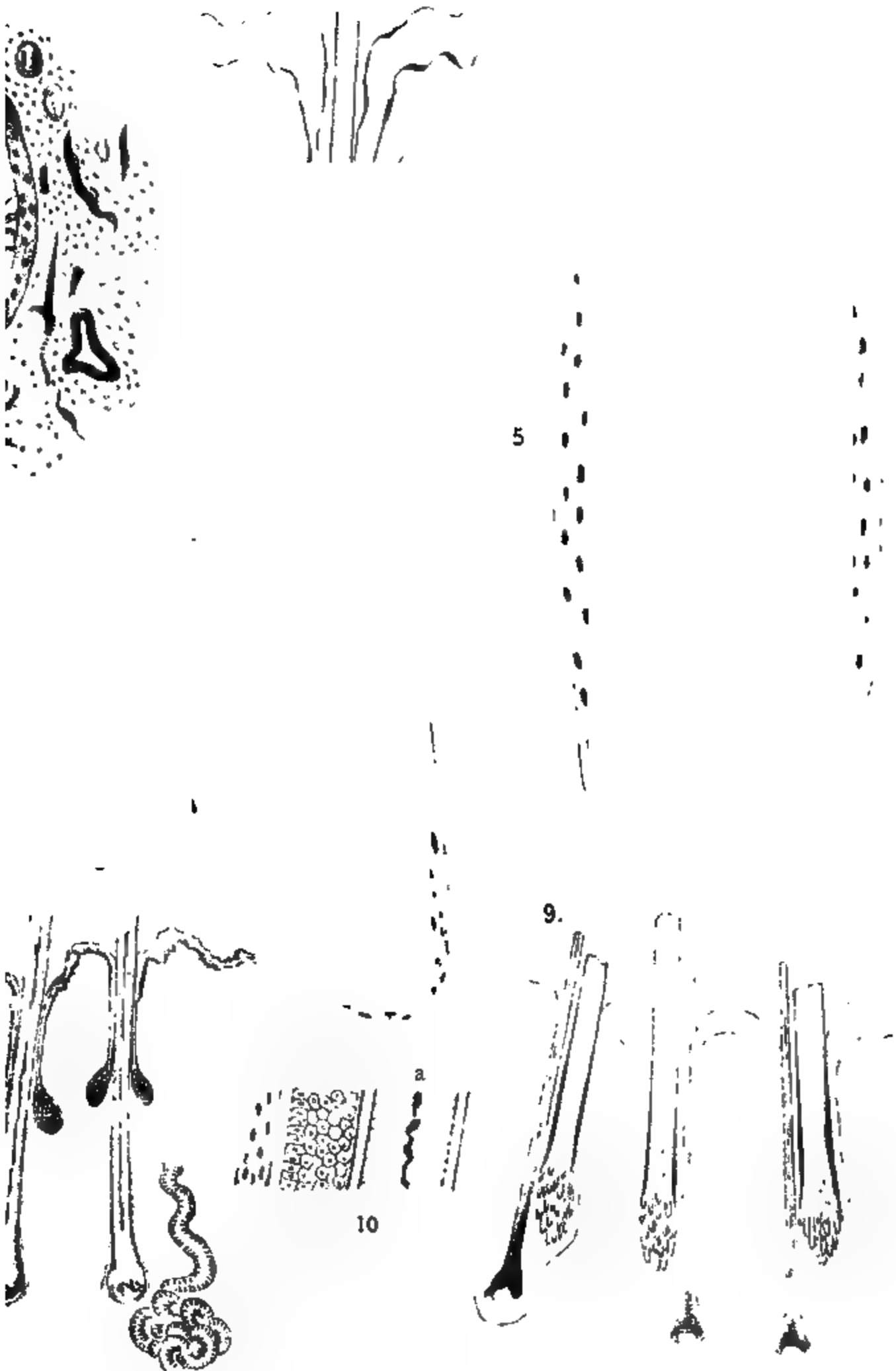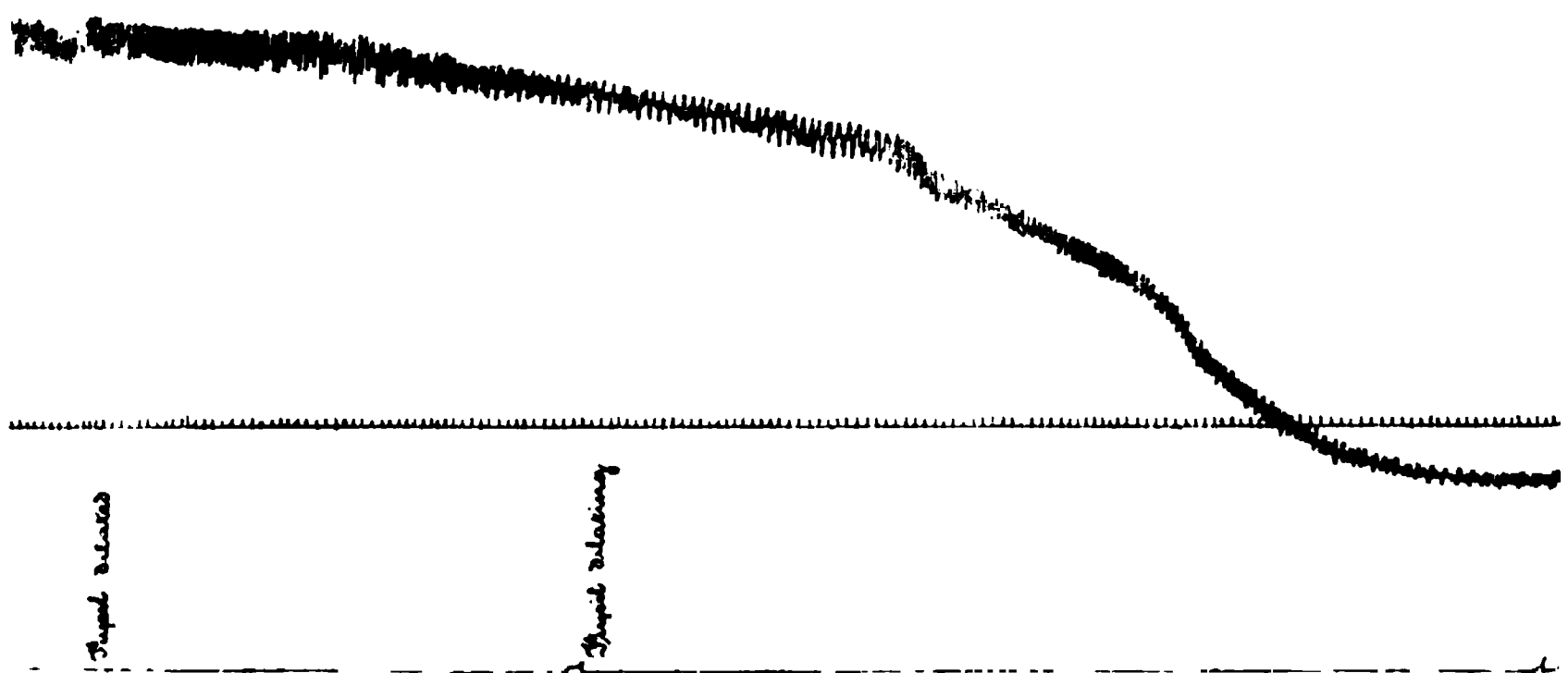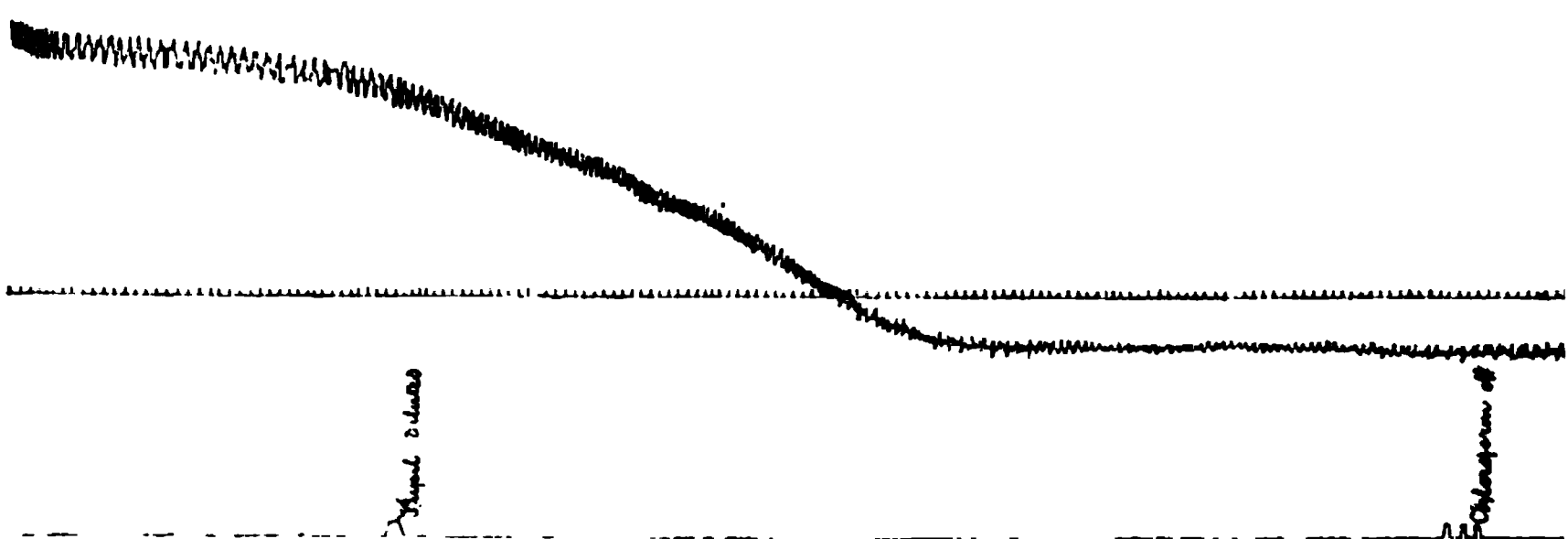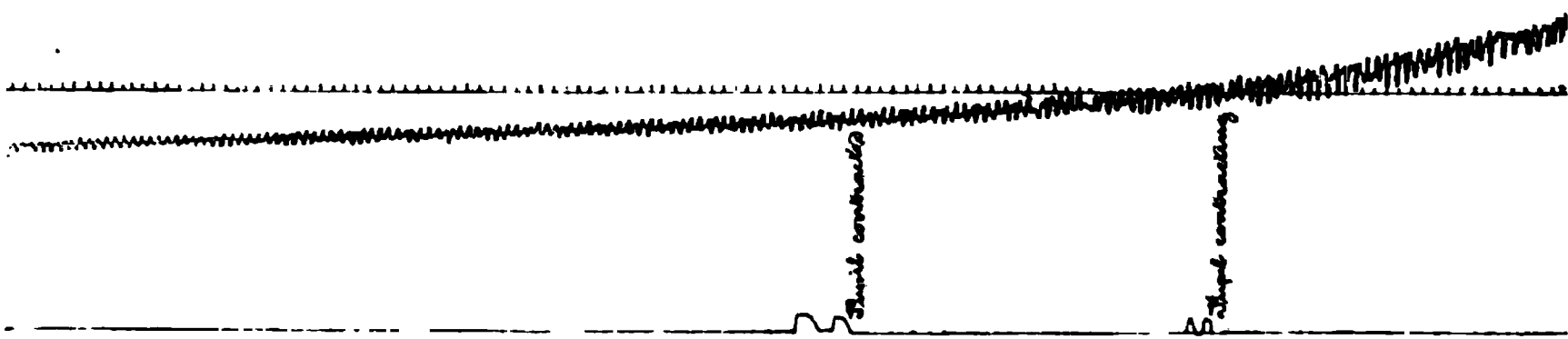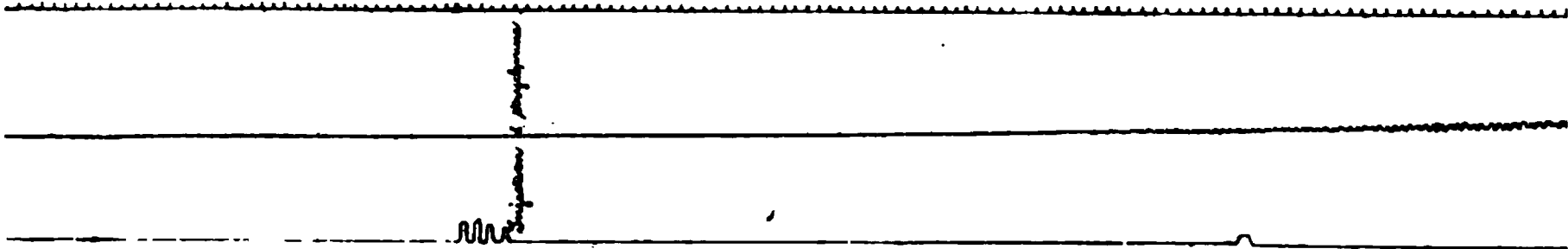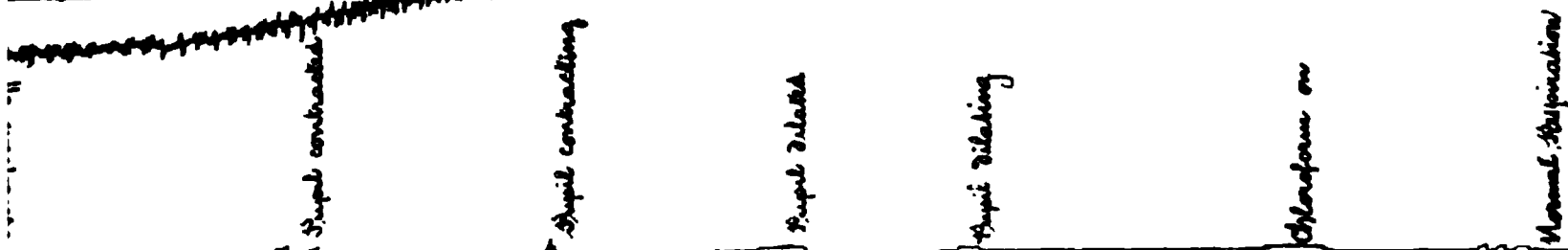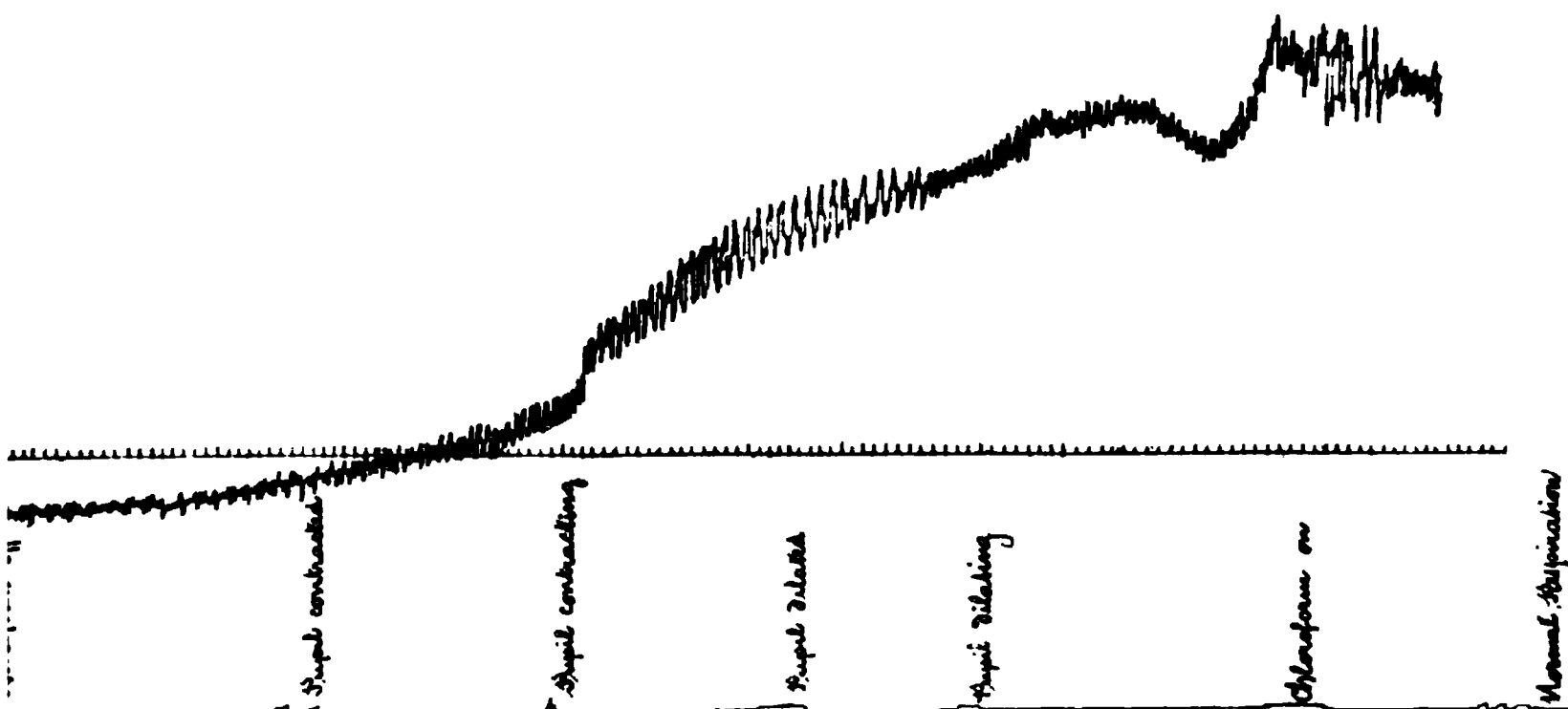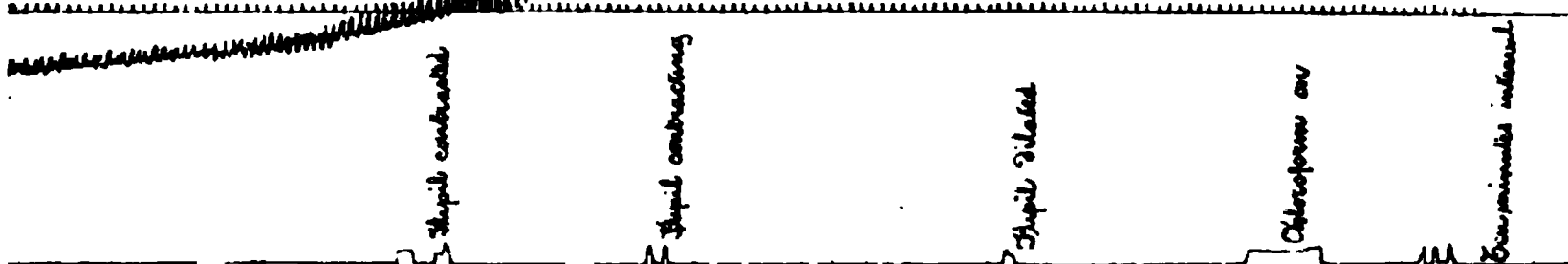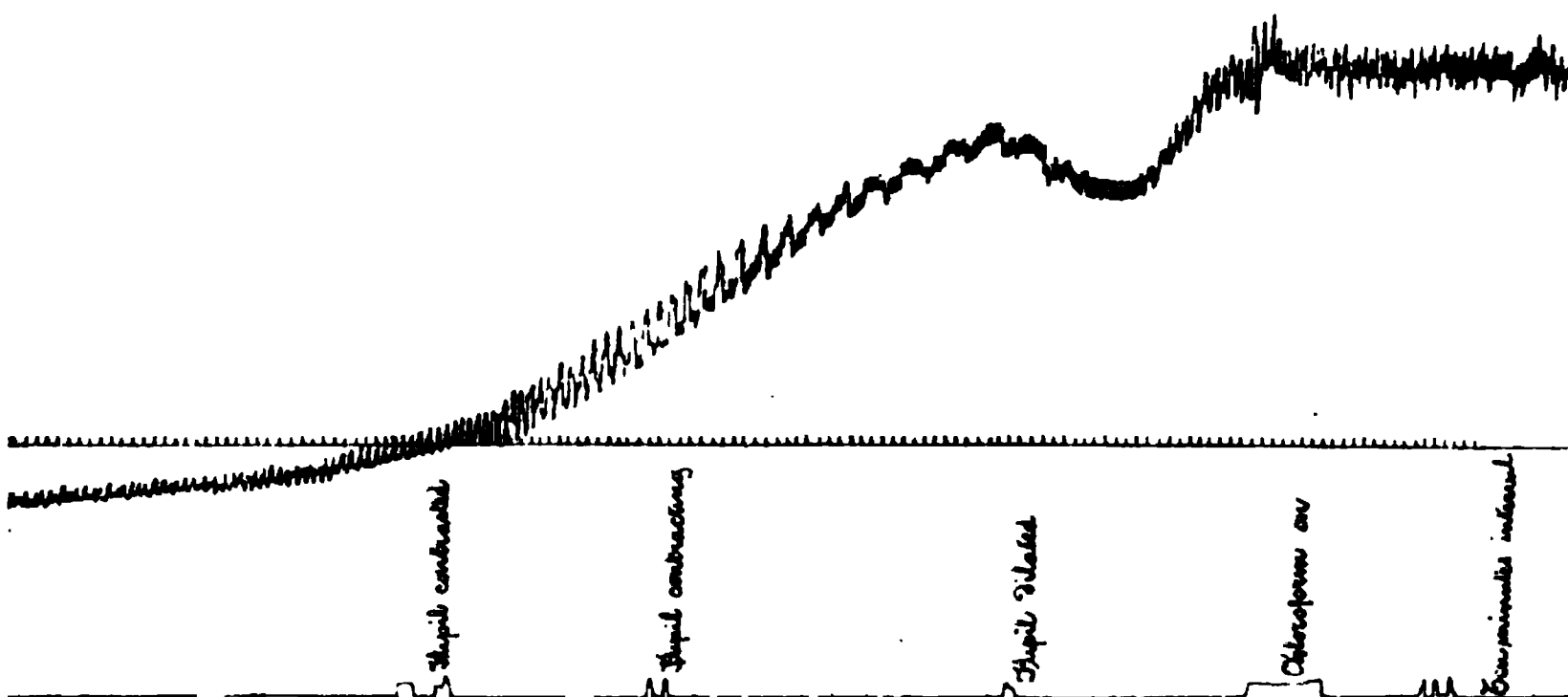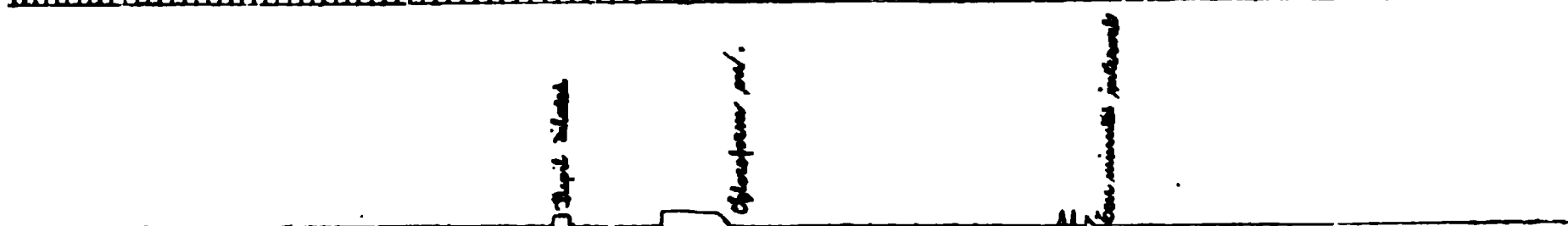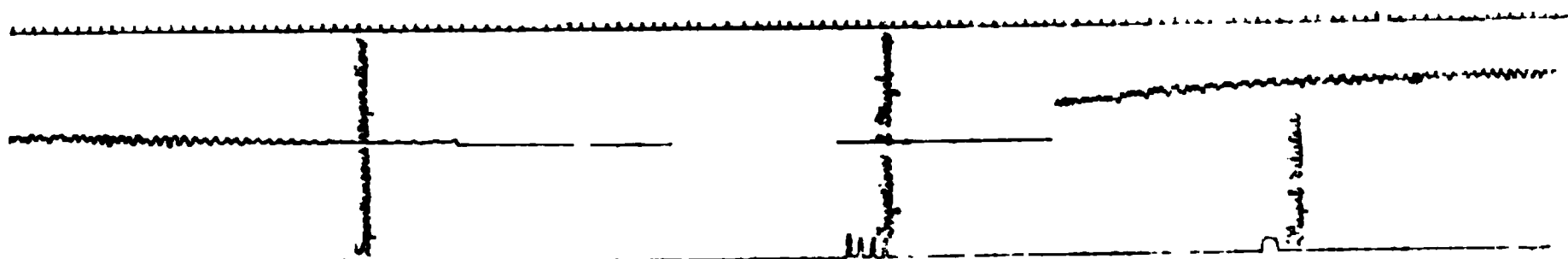
Fig 7
1/24

Left Scapula
OUTER SURFACE.

Fig 8
1/24

Glenoid Cavity
& Coracoid

Fig. 6.
1/24

Fig. 9.
1/12

Left Carpus, &c
(SECTION) DORSAL VIEW

Fig 10.

Fig 11

Fig 12.

III

Digit

II
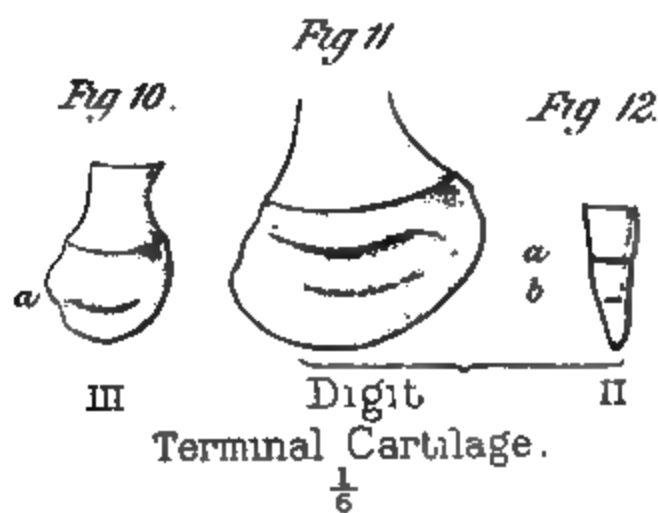
Pectoral Fin.
(LEFT) INNER SURFACE

Terminal Cartilage.
$\frac{1}{6}$

MEGAPTERA   LONGIMANA.

FIC
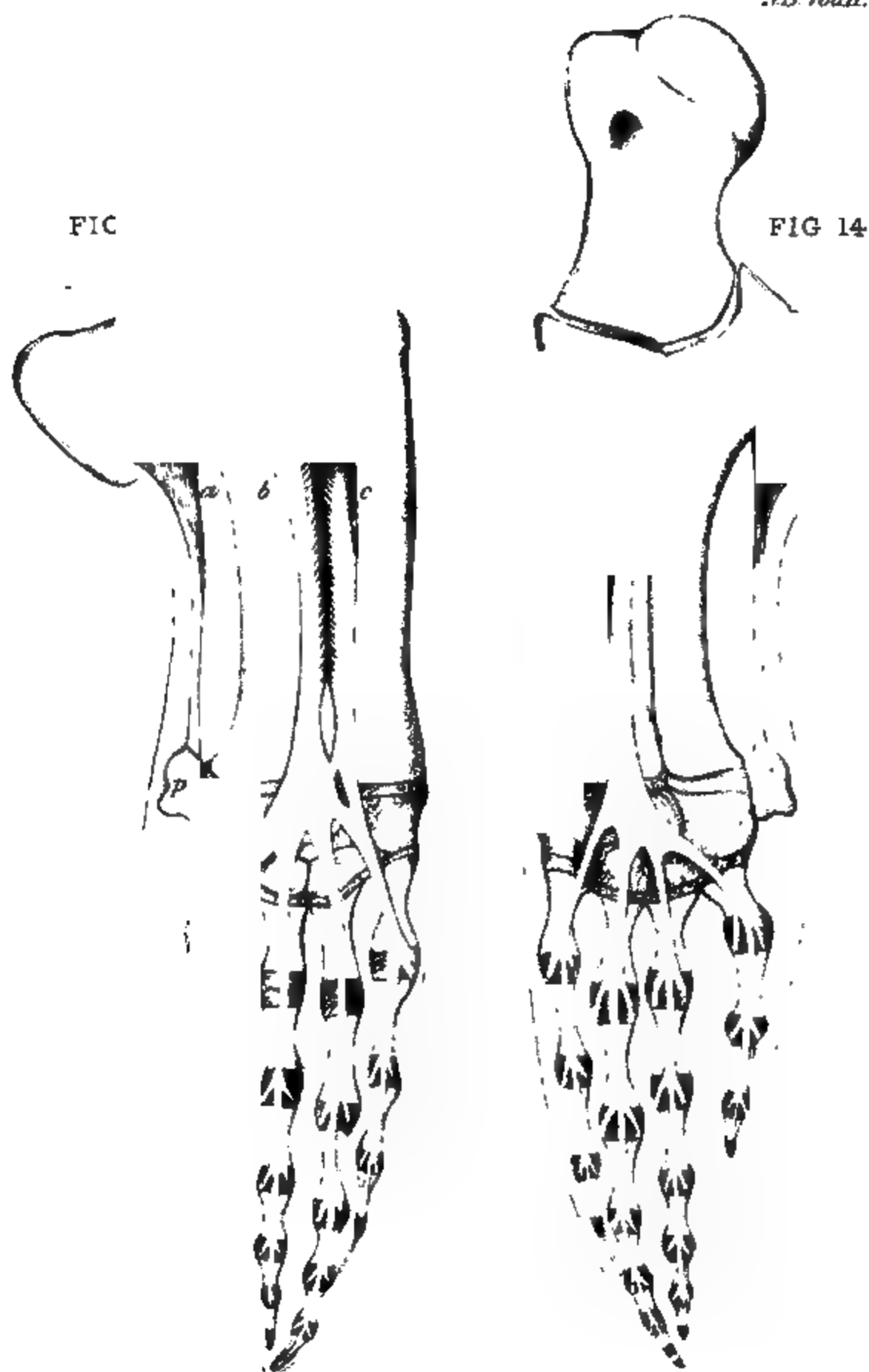
FIG 14

Flexor and Extensor Muscles of the Fingers.¹⁶

FIG 13. Inner aspect *a* Flexor carpi ulnaris   *p.* Pisiform cartilage
b F digitorum ulnaris (F profundus digitorum)
c F digitorum radialis (F longus pollicis)
FIG 14 Outer aspect *d* Extensor communis digitorum

BALÆNOPTERA MUSCULUS.

64 Feet Long
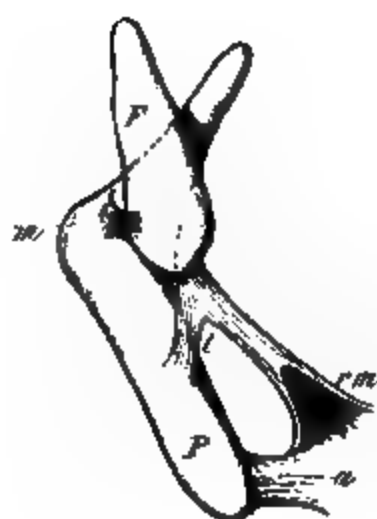
Fig 16
PELVIC BONE
Femur, &c
of
Megaptera
longimana

(FIG 16 Right.)

(FIG 16 Left)

FIG 15 Ligaments Muscles, &c connected with
Pelvic Bone and Femur of
MEGAPTERA LONGIMANA.

John Struthers, del.t

FIG 16
PELVIC BONE
Femur, &c
of
Megaptera
longimana

(FIG 16 Right.)

(FIG 16 Left)

FIG 15 Ligaments Muscles , &ᶜ connected with
Pelvic Bone and Femur of
MEGAPTERA   LONGIMANA.

TH
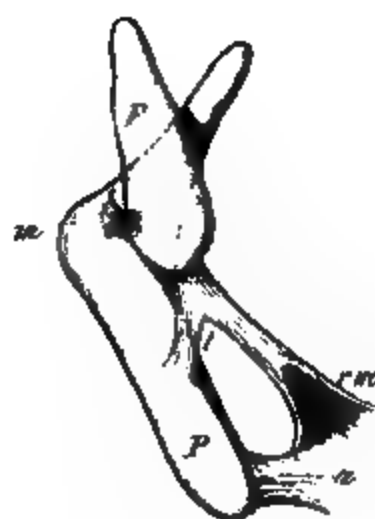
ON THE SKELETON IN THE GENUS *STURNELLA*, WITH OSTEOLOGICAL NOTES UPON OTHER NORTH-AMERICAN *ICTERIDÆ*, AND THE *CORVIDÆ*. By R. W. SHUFELDT, M.D., C.M.Z.S., M.A.O.U., *Memb. Am. Soc. Naturalists, &c.* (PLATES XIV., XV.)

OUR United States avifauna is comparatively rich in its representation of the *Icteridæ* and *Corvidæ*, and through the accidental appearance in Greenland of stray specimens of *Sturnus vulgaris*, ornithologists have also laid claim to having the family *Sturnidæ* added to the list. Eight genera have been created to contain the forms which are at present considered as constituting the *Icteridæ*, and these briefly are the following:—

1. *Dolichonyx* (the Bobolinks), ... 2 species,
2. *Molothus* (the Cowbirds), ... 3 „
3. *Xanthocephalus* (the Yellow-headed Blackbird), . 1 „
4. *Agelaius* (the Red-shouldered Blackbirds). . . 3 „
5. *Sturnella* (the Meadow Larks), ... 3 „
6. *Icterus* (the Orioles), ... 8 „
7. *Scolecophagus* (the Bronzed Blackbirds), . . 2 „
8. *Quiscalus* (the Grackles), ... 5 „

in all, twenty-seven species of these birds. Turning next to the *Corvidæ*, we find them arrayed under two subfamilies, the *Garrulinæ* (Magpies and Jays) and the *Corvinæ* (or Crows), and the following genera and number of species:—

GARRULINÆ
1. *Pica* (Magpies), ... 2 species.
2. *Cyanocitta* (Blue Jays), . . . 5 „
3. *Aphelocoma* (Crestless Jays), . . 4 „
4. *Xanthaura* (Green Jays), . . . 1 „
5. *Perisoreus* (Grey Jays), . . . 5 „

CORVINÆ $\left\{\begin{array}{l} \text{6. } Corvus \text{ (Crows),} \quad . \quad . \quad . \quad . \quad \text{6 species,} \\ \text{7. } Picicorvus \text{ (Nutcrackers), .} \quad . \quad . \quad 1 \quad \text{,,} \\ \text{8. } Cyanocephalus \text{ (Piñon Jay),} \quad . \quad . \quad 1 \quad \text{,,} \end{array}\right.$

a summary which shows two Magpies, fifteen different kinds of Jays, six different Crows, a Nutcracker, and that interesting form the Piñon Jay of the Rocky Mountain region.

Through the labours of previous workers in the osteology of birds we are in possession of quite a full knowledge of this part of the anatomy of the true Crows (*Corvus*), while the two remaining genera of the *Corvinæ* have not been examined, so far as I am aware, with respect to their skeletons.

The osteology of our numerous species of Jays has never been touched upon in detail, while, to say the least of it, the *Icteridæ* have been classified almost entirely upon those characters which are exhibited in their external forms.

: In glancing over this list of species, with the view of picking out some type which would offer a subject as a central figure for description of its skeleton, and from which point the opportunity would be offered me to pass some general remarks upon the osteology of the entire group, I could find no better representative than the genus *Sturnella* for this purpose.

Having decided this much, the present memoir, then, will be devoted to a descriptive account of the skeleton in our Western Meadow Lark (*S. m. neglecta*), together with descriptions or references to the skeletons of such American forms of Crows, Jays, Magpies, Orioles, and others as may be represented in the collections of my private cabinet.

The Skull.

I shall describe the skull from a series of twenty or more specimens which I have collected at different times during the past ten years in widely separated regions. By this means a general description can be given which will apply probably to any skull of the species, for, as we know, birds constitute no exception to the rule among vertebrates, in that, by choosing the extremes from a long series of skulls of any species, graded according to their differences, specimens may be selected which, although they have salient features sufficiently similar to fall

within a prescribed description, yet, at the same time, the two selected skulls may appear very unlike each other.

As an excellent example of this I would invite the reader's attention to the two skulls shown in figs. 11 and 12, which are accurate drawings (× 2) of skulls which I have made from two specimens of our Yellow-headed Blackbirds (*X. xanthocephalus*), collected by me, one in New Mexico (fig. 11, July 1886) and the other (fig. 12, June 1879) in Wyoming. *Xanthocephalus* is one of the genera in the list of our Blackbirds presented above.

Glancing at figures 1, 2, and 3, we observe that *Sturnella* possesses an osseous superior mandible, which is deflected so as to make an angle of several degrees with the cranial axis. In length it is equal to about half the long axis of the remainder of the skull, while in form it is tapering, terminating in a rounded apex anteriorly. Superiorly, between the narial apertures and the apex, the culmen is broadly rounded off, but as we pass backwards on to the naso-pre-maxillary processes this surface is quite flat, and after a point has been passed, which is opposite the posterior point in the periphery of the external nostril, this process dips suddenly down towards the frontal region, and, assisted by the nasal bone on either side, a round eminence is created at the site of flexure (fig. 1). This feature is also well marked in certain other *Icteridæ*, as in *Xanthocephalus* (fig. 11), a feature, however, which may be very feebly pronounced in other individuals of the same species (fig. 12). The infero-lateral edges of this mandible in *Sturnella* are cultrate, and the surface included between them for the most part quite flat. Viewing this part of the skull upon its lateral aspect, we are to note that the narial aperture is of an elliptical outline, with smoothly rounded edges, and no osseous partition, as a septum narium, separating it from the corresponding nostril of the opposite side of the mandible. In one case in thirty, however, this septum may *partially* ossify.

Figure 2 shows the skull of this Meadow Lark upon its superior aspect, and there we are enabled to see that the frontal region is rather broad at its anterior part, though narrow between the orbits. A pit-like depression is found just posterior to the point where the hinder ends of the nasal processes of the premaxillary abut against the adjoining frontal region, and from this point a shallow, median-longitudinal groove is carried back as far as the low parietal eminences. On either side a lachrymal bone (*l*) may be discerned upon this aspect of the skull.

The vault of the cranium is smooth and semi-globose in form; transversely it is broad, and on the whole the brain-case of this bird at once impresses us with its ample size and its capacity, above the average, when taken in comparison with the proportions of its owner, as compared with many other existing birds of or about the same dimensions.

A lateral view (fig. 1) discloses to us the fact that this bird possesses

throughout life a free lachrymal bone (*l*), which superiorly has its extremity wedged in between the pars plana and the corresponding nasal, as shown so well in figure 2. Descending, it is closely moulded upon the antero-external border of the pars plana, but does not quite reach by its lower end the infraorbital bar. This free *lachrymal* is curved like a long slender *f*, its upper end being directed inwards and its lower end outwards. The *pars plana* is very complete, and quite an extensive plate of bone in *Sturnella*, being transversely broader above than it is below, in which latter situation it is tangent to the maxillary rod.

Two large vacuities seem invariably to exist in the interorbital septum; the upper and smaller one merges with the foramen for the first pair of nerves, while the middle or larger one becomes confluent with the optic foraminal opening (fig. 1).

Posteriorly the wall of the orbit is usually quite entire, and at its lower part develops two or three spine-like processes, which are directed downwards and forwards. Similarly directed are the still more prominent and lamina-like sphenotic and squamosal apophyses, springing from their ordinary sites.

When this skull is allowed to rest on a plane surface, with its basal aspect facing downwards, it does so by resting on the extreme tip of the nether side of the superior mandible and the inner facets of the quadrates, while between these two points an arch of no mean depth exists; the line of this arch, or its arc, is well defined by the quadrato-jugal bar for its posterior moiety, while the remainder of the arc, or its anterior moiety, is seen in the infero-external cultrate edge of the premaxillary to its tip.

Viewing next the under side of this skull (fig. 3), we find the occipital area sharply defined by a boundary line, though the space it includes is in no ways raised above the general superficies of this part of the skull, which can best be seen by glancing at figure 1. The foramen magnum is very large, while the occipital condyle is very small. Nothing worthy of special note distinguishes a *quadrate bone* from that element, as it is found in numbers of other Passerine birds. It has two large mandibular facets (fig. 3, *q*) and two mastoidal ones, which latter are perfectly separated from each other by an intervening notch. Either *pterygoid* is a straight and rather stout element, with an expanded distal end, which is applied to the side of the basisphenoidal rostrum, while its proximal end develops a very perfect little cup for the rather large pterygoidal facet on the quadrate. These bones *in situ* fail to meet each other at their palatine heads.

The *palatines* are involved in the flexure of the upper mandible upon the cranium and the arch referred to in a former paragraph, the point of flexure taking place in them opposite the middle of the external narial aperture (fig. 1). From this latter point the palatines, as they pass forwards, merge indistinguishably almost with the premaxillary to form the anterior osseous part of the roof of the mouth.

The postero-external angle of either palatine is drawn out into a spiculaform process of no inconsiderable length, while mesially

beneath the basi-sphenoidal rostrum these bones meet at their ptery-
goidal heads, only becoming continuous beyond, with the finely de-
veloped vomer (*v*). *Maxillo-palatines* of fair dimensions are met with,
and, although strictly Passerine in their arrangement, they are note-
worthy in being produced far backwards, and in tapering gradually
to a rounded tip in each case as they are thus produced.

The *vomer* (*v*) is strongly bifid behind with the limbs, one on either
hand, fusing indistinguishably with the palatine of the corresponding
side. Anteriorly the bone is enlarged, truncated, and exhibits usually
a deep median notch.

I have carefully examined the interior of the brain-casket in a
specimen of one of these Meadow Larks, and find nothing worthy of
particular note; it will be well to observe, however, that the pit for
the hypophysis cerebri is deep and completely surrounded with bone,
while at its base occur, side by side, the double openings for the
carotid arteries.

At the angle of the jaw, on either side, a *mandibular sesamoid* is
found wedged in posteriorly, an element I believe to be present in
both *Icteridæ* and *Corvidæ* (figs. 11 and 12, *ms*).

Turning next to the *mandible*, a very good idea may be obtained of
its general character and form by glancing at figs. 1 and 4, where it
is seen upon two different aspects. Viewed from above it will be
observed that it has the V-shaped form, and that the angular pro-
cesses behind are long and prominent, although they do not curve
upwards to any great extent. The bone is bent at an angle, and in
such a manner as to allow it to properly accommodate itself to the
flexure of the superior mandible on the cranium described above, and
shown in fig. 1. Its symphysis is very deep, and varies in different
individuals. An elliptical ramal vacuity of considerable size is always
present, a feature common to the jaws as found in the majority of
these two groups of birds.

Counting the *sclerotal plates* in the eyes of a number of specimens
of this genus I find *fourteen* to be the usual number present, and this
is probably the average for the vast majority of individuals. They
are of the usual form, all pretty much of a size, and are seen, when
in situ, to overlap each other to some considerable extent.

The *hyoidean arches* of a Meadow Lark constitute a very delicately
fashioned apparatus, and its osseous framework is slender in all par-
ticulars. Preformed only in cartilage, the glosso-hyal consists of two
long rods of small dimensions placed side by side, while posteriorly at
the angles the cerato-hyals jut prominently out, and are in part
ossified.

First and second basi-branchials are fused together, are completely
bony, save the little finishing tip of cartilage behind. The elements
of the great cornua are long and slender, being completely ossified,
and presenting the usual characters of these parts in a Passerine
bird.

With this description of the skull and associate bony parts in
Sturnella before us, let us next take a look at the corresponding parts

in a specimen of *Agelaius phœniceus*, the representative of a genus, as will be seen, that has been placed very close to our Meadow Larks.

We at once observe that the general form of the osseous superior mandible is fashioned pretty much on the same plan as we found it in *Sturnella*; it is proportionately considerably shorter, however, though it also presents the same deflection upon the cranium, with a mounding of the premaxillary and nasals just beyond the frontal region. It rarely or never lacks a complete osseous *septum nasi*, while it agrees in having the external narial apertures of an elliptical outline.

Passing to a superior view of this skull, it might be said to be almost the miniature in general form and appearance of what we saw in *Sturnella* (fig. 2), and really requires no detailed description beyond what I have already indicated above for this latter form. On a lateral aspect, however, we at once meet with quite an important distinction between the skulls of these two birds, for in *Sturnella* we found a free lachrymal bone, while here, in *Agelaius*, this element has been completely absorbed in the adult with the anterior superior angle of the pars plana, leaving no trace whatever of its sutural boundaries.

The *pars plana* itself is an ample plate of bone, as we found it in *Sturnella*, that completely partitions the orbit off from the rhinal space, and shows a rounded and conspicuous notch at the middle of its external margin, a feature also characteristic of this part of the skull in the Meadow Lark.

Two large vacuities are present in the interorbital septum, similar to those shown in fig. 1; while the lateral processes of the skull, as well as those peculiar spiny projections upon the posterior orbital wall, are very much the same as they occur in *Sturnella*. Indeed, if we set aside the fact of the different conditions of the lachrymal bone, it is not difficult to trace the affinities of these two birds, even by a casual study of the lateral aspects of their skulls alone. Almost precisely the same forms and arrangements characterise the several parts found upon the basal aspect of the skull, as I have figured them for *Sturnella* (fig. 3). Proportionately, perhaps, the *maxillo-palatines* are a little longer, and come rather nearer together in the median line; while in *Agelaius*, too, the palatines are bent more downwards anteriorly, and at the same time their postero-external angles are drawn out into even more prominent spiculaform processes than we found them in the Meadow Lark.

A large ramal vacuity characterises the *mandible* of this blackbird, as in other members of the group, and a good-sized mandibular sesamoid is also present at the angle of the jaw. This bone, however, is principally distinguished from the one in *Sturnella* by being nearly one-half smaller, in being proportionately shorter, in having deeper ramal sides, and in having the posterior angular processes also proportionately shorter. In making these distinctions, we must bear in mind that, in so far as *form* alone is concerned, the mandible, as well as the skull itself, will present us with precisely the same class of variations in a series of specimens of *Agelaius* as I have found and elsewhere shown for the Yellow-headed Blackbird (figs. 11 and 12 of the present paper).

The *hyoidean apparatus* and the *sclerotal plates* of the eyeball are very similar in *Agelaius* to what we have already found them to be in *Sturnella*.

But the question may now be fairly asked—How would you distinguish a series of skulls of *Sturnella magna neglecta* from a series of skulls of *Agelaius phœniceus?* Primarily, I would say by their *size* (not that size itself constitutes a character), for the largest skull of a series of the latter is always considerably smaller than the smallest skull of a series of skulls from *Sturnella*. Measured on an imaginary straight line, extending between tip of beak and the most posterior point on the summit of the "occipital prominence," fifty skulls of *S. m. neglecta* will average for this distance 5 centimetres, while fifty skulls of *A. phœniceus*, measured in the same way, will average 3·6 centimetres. Then the mandibles of *Sturnella* are proportionately *longer* and rather less deflected on the skull than they are in *Agelaius* as a rule; neither of which facts, however, do I attach much weight to. As a character, however, we find a *free* and peculiarly formed *lachrymal bone* in *Sturnella*, which element has in the adult *Agelaius* become indistinguishably fused with the *pars plana*.

Beyond these distinctive differences and diverse characters, the skulls of these two birds, then, are very evidently modelled upon the same plan, and depart from it in either case no very great distance. Indications based upon *single* characters, however, *must* be taken very guardedly; for were one to picture in his mind the external appearance two such forms would present, in so far as their differences were concerned, as the Coot (*Fulica*) and a Rail (*Porzana*), judging from an examination of their skulls alone, I think he would be very much surprised indeed, when the two birds were introduced to him, at his discovering how very much unlike they really were in their external forms. Fundamentally, and otherwise, their skulls are almost identically alike, except in point of size.

Let us next, then, take the skulls of some of our typical *Icteridæ*, and see what we can make of them. I have two species represented: (1) Bullock's Oriole (*Icterus bullocki*), which I collected at Fort Fetterman, Wyoming, in 1879, and (2) the Orchard Oriole (*I. spurius*), which I find I collected in New

Orleans, La., in July 1883. The skulls of the former *average* considerably larger than the skulls of the latter; but it is surprising to see how wonderfully like the skull of a specimen of *I. bullocki* is to the skull of a specimen of *Agelaius phœniceus*. Their lengths, obtained in a manner as pointed out in a foregoing paragraph, average about the same, 3·6 cm.; and actually in detail of form their skulls are marvellously similar to each other. Were fifty selected specimens of the skulls of one species (*I. bullocki*) mixed up with fifty selected skulls of the other species (*A. phœniceus*), and I were called upon to assort them correctly, I would be obliged to depend upon the following characters:—(1) The deflection of the superior osseous mandible on the cranium is *less* in the Oriole than it is in the Blackbird, while this part is rather broader at the base in the former than it is in the latter bird. (2) In the Oriole the mounding on the culmen, engaged in by the nasals and premaxillary, just beyond the frontal region, is markedly less prominent than it is in the Blackbird, while the external narial apertures are relatively much larger in the first-mentioned species. (3) The sides of the rami of the mandible in the Oriole are shallower than they are in the Blackbird, and the *ramal vacuity* is reduced to a narrow longitudinal slit in the former, whereas in the Blackbird it is always an elliptical foramen of some size, much as we see it in the mandibles of the skulls shown in figs. 11 and 12. (4) The septum narium is but incompletely ossified in the Oriole. Beyond these three distinctions there are no characters which I have been enabled to discover upon which I could rely with any degree of certainty whatever, in separating the aforesaid hundred skulls from each other, so that one lot would contain the skulls of the fifty Orioles, and the other lot all the Blackbirds.

In the case of *Icterus spurius* we find a very much smaller skull, and more delicately fashioned one than in *I. bullocki*; the flexure of the superior osseous mandible on the cranium is barely noticeable; the mounding of the culmen in front of the frontal region has almost entirely disappeared; the external narial apertures are relatively much larger; and finally, although the Icterine characters are still strongly pronounced in this skull, there is a general indescribable *facies* about it which

recalls to our mind the skulls of Passerine birds standing in among such forms for instance as *Motacilla*, or a large *Anthus* with a little modification, and some others.

Leaving the *free lachrymal bone* out of the question, as a peculiar departure pertaining to *Sturnella*, I would say that the gap between *Sturnella magna* and *Icterus spurius*, in so far as their skulls seemed to indicate, was fully three or four times as great as the gap which exists between *S. magna* and the genus *Agelaius*.

In the genus *Xanthocephalus* we again return to a type of skull seen in *Agelaius*, and already described above (compare figs. 11 and 12). Were it not for the marked difference in size, *Xanthocephalus* being about one-third larger, it would be very difficult indeed to distinguish them apart, taking for example a series of fifty of each skull. The septum narium in *Xantho-cephalus* rarely or never ossifies to any extent.

Elsewhere I have called attention to the matter of individual variation exhibited on the part of the skull in this Yellow-headed Blackbird, but this is but a common trait to the skulls of all vertebrates (figs. 11 and 12).

Could it be possible to reduce in size a series of skulls of *Xanthocephalus* so that they would be equal in this respect to a similar series of skulls of *Agelaius*, and I were called upon to assort the lot, after they had been mixed up together, so as to properly designate the two species, I see but three characters upon which I could rely in order to be successful in such a task. These are—(1) in *Xanthocephalus* the external margin of the *pars plana* is, following it for its entire vertical length, a long shallow concavity, while in *Agelaius* this margin exhibits, at near its middle, a well-defined and rounded notch. Again (2), in *Xanthocephalus* the postero-external angles of the palatines are not markedly produced as definite apophyses, while in *Age-laius*, as we have already seen, these parts are drawn out into conspicuous and spicula-like processes. Finally (3), the septum narium is, as a rule, always completely ossified in *Agelaius*, and rarely so in *Xanthocephalus*.

My collection contains a very nice series of skeletons of the bird representing the next genus to be considered—*Scole-cophagus cyanocephalus*. These have been obtained from

specimens which I have collected at different localities, widely separated, during the past seven or eight years.

The skull in one of these blackbirds—the Bronzed Blackbird— is about one-fourth larger on the average than is the skull of *Agelaius phœniceus*, of which it seems to be almost the exact counterpart, even to its minor details. As a rule, however, its superior osseous mandible is not so pronouncedly flexed upon the cranium, nor are the postero-external angles drawn out into the spine-like processes, as we found them to be in *Agelaius*, and its septum narium may not ossify as perfectly. These points, and its size, would at once distinguish the skull from one of the last-named genus, had we the two to compare in our hands.

The external margin of the pars plana in *Scolecophagus* shows the characteristic rounded notch as in *Agelaius*, which notch is broader in *Sturnella*, and accommodates the descending limb of the free lachrymal found in that genus, an element which, as in the other blackbirds, has been in the adult completely and indistinguishably fused with the pars plana.

Turning next to some skulls of *Molothrus ater*—the Cowbirds—which have also been placed in the *Icteridæ*, we are at once struck with the wonderful resemblance, by no means a superficial one, they bear to the skulls of many forms of the true *Fringillidæ*. In comparing an average skull from a specimen of *Molothrus ater* with a skull of *Calamospiza melanocorys*, and judging from this part of their economy alone, it would be difficult indeed to say wherein violence would be done by placing both the birds in the same family,— I almost said genus.

I am sorry to say that I have not at hand, nor am I at present in a country where I can collect them, a series of skulls of *Dolichonyx oryzivorus*, but I am strongly inclined to believe that the skull in it will be far more like the typical skull of a Conirostral bird, than it is like a typical Icterine one.

In *typical* Fringilline birds, as in *Calamospiza*, for instance, we *always* find those tympanic enlargements, one of which overarches the entrance to either ear in the dried skull, large, swelling, and semi-transparent; whereas, in *Molothrus*, they

are not especially conspicuous, and appear very much as we find them in *Icteridæ*. Again, the *maxillo-palatines* are more slender, shorter, and further apart in the Finch than they are in *Molothrus*, in which latter bird they more nearly agree with those processes as we find them in *Agelaius*. In both birds, on the other hand, we find the spine-like processes *absent* from the postero-external angles of the palatines so manifest in the Red-shouldered Blackbirds. True as all this is, we have to go no further than the skulls of the Tanagers (*P. ludoviciana*) of an allied family, to find a skull which, in most particulars, repeats the general characters of the skull in *Xanthocephalus*, for instance, and has the long maxillo-palatines, and conspicuous as well as long apophyses projecting backwards from the postero-external angles of the palatines. But we are digressing, and, were we to travel far in that direction on the present occasion, we fear that we would soon have more knotty points about our ears to disentangle than the limits of this memoir call for, or fall within the scope of its title.

To return, and judging from the general facies of the skulls alone, however, I would say that such a form as *Molothrus* was more nearly affixed to *Scolecophagus* than it was to the *Calamospiza*, but what the other parts of the skeleton will develop we will see further on.

Great as are my regrets at having been unable to say anything about the skull of such a common bird as *Dolichonyx*, they are none the less when I find that *Quiscalus* is also absent from my collection, and my efforts to secure one during the past two years have signally failed.

At some future time I trust to supplement the work in the present memoir by notes upon the skeletons of these two important genera. From my recollection of them alone, however, I am inclined to believe that the skull of *Dolichonyx* will be found to be even still more Fringilline in character than is the skull in *Molothrus*, and further, that the skull in *Quiscalus* will be perhaps shaded towards the *Corvidæ*. From what will follow, it will be interesting to know whether or not the *lachrymal bone* is a free element in the skull of *Quiscalus*.

Having these facts now before us, as well as the figures illus-

trating the salient features in the skulls of our United States *Icteridæ*, I think we are in a position to pass the general characters of a few of the skulls of the American *Corvidæ* in review, and thus be enabled to compare the similarities and the differences in this part of the skeleton in the two groups of birds.

Osteologically the *Corvidæ* of our American avifauna are pretty well known, and even a superficial examination of their skulls is sufficient to satisfy us that in this particular, at least, they are as a group of species quite closely affixed.

In connection with an extensive memoir on the myology of birds, now in the hands of the Smithsonian Institution for publication, I have very fully illustrated by drawings the skeleton of our *Corvus corax sinuatus*, so I have not deemed it necessary to simply reproduce those figures here.[1] Although I described the Raven in the paper I refer to as *C. corax sinuatus* I am inclined to believe that it may eventually prove to be a hitherto overlooked species.

The following facts have tended to influence me in forming this opinion:—About a year ago Dr Thomas H. Streets, of the U.S. Navy, sent me a fine collection of birds' skulls which he had collected while cruising in the Pacific Ocean; among these was the skull of an exceptionally large Raven, collected by him in South-eastern Alaska in August 1885. It is a very large one, but apparently not too large for a specimen of true *Corvus corax sinuatus*. Now in New Mexico here, the Ravens I have collected are considerably smaller, and in point of size agree pretty well with the south-western Raven, described by ornithologists as the White-necked Raven (*C. cryptoleucus*), the distinguishing character in which latter bird is its possessing *concealed white* feathers at the supero-posterior region of the neck.

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[1] Likewise, I have given, in the second edition of Professor Elliott Coues' *Key to North American Birds*, p. 172, fig. 79, the basal view of a skull of a Raven, which shows very well the characters of those parts. The lettering upon that figure is my own, but I am not responsible for the description beneath it. The author of that work there says that "V goes to the ossified nasal septum borne upon the end of the vomer, which latter bone begins at the thickest part of the central projection." The latter part of this statement is quite correct, but V in the case cited *does not go to the nasal septum* but to an osseous prolongation of the upper part of the *vomer*, which character is often seen there in the true *Corvinæ*, and is distinct from the *unossified* nasal septum of a Raven.

Now, I have plucked a number, some fifteen or twenty, of these Ravens in North-western New Mexico, and have yet to find one (in the winter) which has any concealed white feathers anywhere in its plumage. It is my intention to still further investigate this matter.

In figures 8, 9, and 10 I have represented the three principal views of the skull of an American Magpie (*Pica pica hudsonica*), of the size of life.

They give all the characters as we find them in the Corvine skull; and the typical Jays only depart therefrom to an extent which will hereinafter be quoted.

In a Magpie we find the superior osseous mandible to be rather broad at its base, tapering gradually to its apex, somewhat decurved, sloping sides, cultrate infero-external edges, a gracefully downwardly curved culmen, and with large subelliptical external narial apertures, which have smoothly-rounded margins.

Viewed from above (fig. 9), we note that the peripheral borders of the orbits are sharp and clean cut, while the shortest transverse distance between them is not inconsiderable. The vault of the cranium is smooth, rounded, and ample, giving all the indications of a capacious brain-cavity within.

Regarding this skull upon a lateral aspect (fig. 8), we observe that it too, as in *Sturnella*, possesses a free lachrymal bone, occupying very much the same position, and having very much the same form, as it has in the Meadow Lark; it differs, however, in not inserting itself so high up between the nasal bone and the pars plana, and consequently cannot be seen so well upon an upper view of the skull in a Magpie or Crow. The *pars plana* is a roughly quadrate plate, having an open slit above it, which separates it from the nether side of the frontal bone above. It is, however, joined at its supero-external angle.

Being essentially Passerine in form, the *quadrate* is notwithstanding notable for its long orbital process with its expanded extremity. Both sphenotic and squamosal apophyses are fairly well developed, with a moderate concavity between them to pass the temporal muscle in the living bird. The external aperture of the ear in the dried skull of this Magpie, a feature common also to most Crows and Jays, is very large and flaring, admitting of a full view of the parts within.

Directing our attention next to the base of this skull (fig. 10), we find that anteriorly between the outer sharp edges of the premaxillary the osseous roof of the mouth is entire, and composed of a firm, somewhat concave, bony plate. The hinder margin of this plate is sharp, but in some specimens of Crows and Ravens is rough and jagged. As in the *Corvinæ*, the anterior limbs of the *palatines* are wide apart here, as their extremities merge with this bony roof of the mouth at its sides.

Posteriorly, the upper and lower median lamina of the palatines curve towards each other, the lower terminating in a free edge with pointed anterior extremity, the two being separated by some little interval mesially, while the upper moulds itself on the under side of the basi-sphenoidal rostrum, and it, too, is separated from the corresponding edge of the palatine of the opposite side by a slight interval. These bones, however, usually meet at their pterygoidal heads in this situation. The postero-external angle of either palatine is bluntly extended backwards for a short distance, and in each case, at the under side, an oblong facet is to be seen, intended for muscular insertion.

Describing the palatine structure in a Raven (*Corvus corax*), Huxley said:—

" This structure, which I term ægithognathous, is well exemplified by any of the typical Passerine birds, as, for example, a Raven.

" The vomer is a broad bone, abruptly truncated in front, and deeply cleft behind, embracing the rostrum of the sphenoid between its forks. The palatines have produced postero-external angles. The maxillo-palatines are slender at their origin, and extend inwards and backwards obliquely over the palatines, ending beneath the vomer in expanded extremities, which do not become united by bone, either with one another or with the vomer. The anterior part of the nasal septum (in front of the vomer) is frequently ossified in ægithognathous birds, and the interval between it and the præmaxilla filled up with spongy bone ; but no union takes place between this ossification and the vomer " (*Proc. Zool. Soc.*, 1867, pp. 450, 451).

This clear description applies equally well to the skull of the Magpie now under our consideration; and with reference to footnote 1 of the present paper, I would again invite attention that Huxley says that no union ever takes place by bone between the vomer and such part of the *anterior* portion of the septum nasi as may occasionally ossify. In the *Corvinæ* this ossification takes place only to a limited extent.

Further, I would supplement this description of Huxley's by saying that the vomer in Crows and their nearest allies is not only truncated anteriorly, but as a rule shows a rounded notch in the median line in front. Moreover, it is almost *tubular* in form, as in the Magpie in my hand, which is quite so, and wherein, too, the *notch* I have just described is absent. In the Raven's skull, however, the one Dr Streets secured for me, a longitudinal gap is open for the entire length along the superior aspect of the vomer, and a concavity occurs at either side of the bone in this specimen.

In *Pica* the *pterygoids* are slender in so far as their shafts are concerned, but their palatine heads are much dilated, and are tangent to each other beneath the rostrum of the sphenoid, while at its sides their expanded portions are spread out upon its surface, the rounded basi-sphenoidal rostrum being, as it were, closely held between their grasp. The *occipital area* is rounded, with the bounding occipital ridge but faintly marking its natural confines. *Sturnella*, as we have stated above, has this area of a cordate outline (fig. 3).

All *Corvidæ* possess that little osseous tube known as the *siphonium*, which gives passage to the air from the tympanum to the pneumatic cavity in the end of either limb of the mandible.

The *hyoid arches* are very thoroughly ossified, and in them we find the basi-branchials fused into one stout median rod, terminated behind by an unusually long piece of cartilage. The thyro-hyals are long and slender rods, and also completely formed in bone. The anterior end of the basi-branchial is enlarged and seized between the cerato-hyals, offering to each one a facet for articulation on either side. For the most part, too, the glosso-hyal is ossified, being fused together in front, but diverging as we proceed backwards, leaving a long triangular median vacuity just in front of the basi-branchial.

The *mandible* of this Magpie's skull is a V-shaped bone, with moderately high ramal walls, which latter are perforated on either side in their proximal thirds by an elliptical vacuity of no very great size. If we glance at figure 8 of the Plate, we observe, too, that the posterior articular processes are not very powerfully developed, while the inturned ones are a conspicuous

feature of this bone. These latter have the usual single pneumatic foramen at their upper sides and near the base in each case.

Ravens and Crows have, of course, very much larger skulls than a Magpie, being in proportion to their size, but these skulls repeat, in their structure and the arrangements of their parts in almost every detail, what we have just gone over and described as pertaining to the skull in *Pica*. This statement applies with equal truth, too, to the associated ossifications of the skull, as the mandible, the hyoidean apparatus, the siphonium, the sclerotals of the eyeballs, and other structures.

Difficult as it is to put your finger on any particular character, or set of characters, which would enable one to say that the skull of a Magpie is more like the skull of a Crow or Raven than it is like the skull of a Jay, yet upon careful comparison I find that, in addition to the similarity of their general facies, the osseous superior mandible in a Magpie much more closely resembles the corresponding part in a Crow than it does that of the Jay—any American Jay. Moreover, the palatine bones in a Magpie are actually more Corvine in form than they are Garruline. Passing through a series of skulls, however, headed by the skull of an old Raven and including a Crow, a Magpie (*Pica*), several typical Jays, and a *Sturnella*, I can only say that the gradual differential shading of the entire structure from one form into another is quite as beautiful as it is perplexing. Performing this feat carefully it still leaves the impression strongly upon my mind that *Pica* is nearer *Corvus* in its skull-structure than it is to *Cyanocitta*, or *Aphelocoma*, or the rest.

The systematists of the American Ornithologists' Union have placed *Pica* among the Jays (*Garrulinæ*) and retained *Cyanocephalus* and *Picicorvus* among the *Corvinæ*. Just at this point I fail to see in the skull of *Pica* the justification for such an arrangement; though perhaps further on the remainder of the skeleton in the several interested forms may throw some light on this subject. Very much do I regret to say that, although in former years I have collected specimens of *Picicorvus*, my cabinet at present does not contain the skeleton of that interesting bird.

During the spring of 1881, Mr C. A. Allen of Nicasio, California, presented me with a very fine specimen of *Cyanocitta*

stelleri, from which I obtained a complete and excellent skeleton. But I have the skeletons of a number of other Jays before me besides.

Now, upon critically comparing the skull of this Jay (*C. stelleri*) with a Magpie's skull, I find them, as I have already said, wonderfully alike in the vast majority of their structural details, with the exceptions already noted in a preceding paragraph. The entire form of the superior osseous mandible in the Magpie is fashioned as we find it in the true Crows (*Corvus*), and easily distinguishable from the corresponding part in the Jay; again, the under side of the hinder expanded portion of a palatine, in a Crow or Raven, has a very characteristic form (see Huxley's figure of a Raven in *Proc. Zool. Soc.*, 1867; my figure in Coues' *Key*, both quoted above), for at the postero-external angle of this aspect there is developed a conspicuous *oval facet* for muscular insertion (see fig. 10), and the bone has also as I say a characteristic shape here. Now in the Jays, the form of this part of the palatine is notably dissimilar from this, and the facet referred to is *absent* in *Cyanocitta*, but may appear sometimes as a feebly developed *point*.

This character alone lends to the basal view of the skull of a Magpie a true Crow-like appearance, not enjoyed by the same view in the skull of any of the typical Jays.

That curious and highly interesting bird, our Piñon Jay (*C. cyanocephalus*), presents in its skull the veritable shadings that stand exactly between the two subfamilies,—it is Corvo-Garruline in the strictest sense of the word, so far as its skull is concerned. But its skull presents also another exceedingly interesting feature, for its superior osseous mandible possesses two of the characters seen in the skull of *Sturnella*,—for it shows a certain amount of flexure upon the cranium and a very noticeable elevation of the culmen just beyond the frontal region. I have some eight or ten skulls of this bird before me, and find that both of these characters are better marked in some individuals than they are in others, but this also obtains, as we are aware, with specimens of *Sturnella* alone.

Now my collection contains many other skeletons of Jays, and Crows, both adult and young, all of which I have carefully gone over, as I have the skeletons of many of *Icteridæ* and *Fringillidæ*.

And in Hayden's *Twelfth Annual* will be found my exhaustive description (with plates) of the skeleton of *Otocoris*.

There remains nothing, however, worthy of a more extended description, so far as the skull goes, in the present connection, beyond what I have already attempted to present above, for, as I have already remarked in a general way, the skeleton of both these groups is fairly well known.

As to what our examination of the skulls of the *Icteridæ* and *Corvidæ* has brought out and seems to indicate, I will defer stating until the close of this memoir, as it can then be more intelligently presented after the remaining parts of the skeletons under consideration have been duly passed in review.

Of the rest of the Axial Skeleton.

Among the various species of birds we find that, in common with the rest of their economy, the vertebræ are characteristic for each—characteristic in the main for any species, both in their form and arrangement. There are exceptions, however, as we often see in man himself, as to the arrangement of the ribs. Men are found upon the dissecting-table sometimes wherein the dissector will discover that his subject possesses a pair of cervical ribs ; this case will also be found to hold true in birds, for they, too, vary sometimes as to the number of free cervical ribs they may possess. We sometimes find, for example, that in a certain species of bird, the 12th cervical vertebra may have a pair of tiny free ribs, whereas in another individual of the same species, these free riblets may not be found until we arrive at the 13th vertebra.

Again, as to form. I suppose if we were to take the cervical and dorsal vertebræ from fifty specimens of *Sturnella*, carefully examine them, and compare them over and over again, and then formulate a full description of their average characters until we were absolutely familiar with each and every vertebra, and then pass to a similar series, to be similarly dealt with, from fifty specimens of such a bird as *Pica*, for example, we could in time be able to detect the average distinctive characters for these birds, and so on, through any family of birds ; but I take it it will be a long day before we come to make use of the spinal column in Aves in any such way—although there is not a doubt in my mind as to the fact that it could be done, and constant *average* differences be found for the several species.

Sometimes I am inclined to believe that one of the best characters, and perhaps most reliable for birds, is the comparison of the sum of

the free vertebræ to be found between the skull and the pelvis, *i.e.*, the aggregate of the cervical and dorsal segments. In the long run, surely this number should be quite constant for the species at least, and very rarely should we find a vertebra added or subtracted in any case. As I have already hinted, far less constant than this character is the arrangement of the ribs, especially as to the question as to which pair of cervical pleuropophyses first become liberated as ribs ; for, of course, however small they may be, the moment they are dissociated from the vertebra, that moment we must count them as true cervical ribs; and as unimportant as this trivial circumstance is in birds, where I have reason to believe that it is not of unfrequent occurrence, it is still important when we come to endeavour to use the number of cervical vertebræ *without* free ribs, as a comparative character in our comparison with some other species, belonging perhaps to a different family.

Again, we must believe that the number of vertebræ which unite to form the pelvic sacrum is quite constant for the species, while, on the other hand, the number of free caudal vertebræ may vary again for the *species*.

If the number of vertebræ fused together to form the pelvic sacrum in any species of bird is found to vary, it is in the vast majority of cases due to the liberation of the ultimate segment; thereby adding an additional vertebra to the caudal series in the individual wherein it may chance to happen. Very rarely do we find in any bird that the usual arrangement for the vertebræ in its spinal column is violated through the appropriation, on the part of the sacrum, of the last dorsal vertebra. Sometimes we will find, in the case of the caudal vertebræ, that the pygostyle will take up one more segment than it is as a rule entitled to for the particular species, in which case the caudal series, of course, loses one in its total count. Or it may gain one by the pygostyle failing in a certain case to appropriate the usual number of segments to which it, as a rule, is entitled for the species wherein this last accident may occur. With these facts before us, let us consider the spinal column in some of the species of birds we have under consideration in the present memoir, and first, as to its subject—*Sturnella*.

In all the specimens of *S. m. neglecta* before me, there are eighteen vertebræ in the cervico-dorsal region of the spinal column. No free ribs are to be found upon the first eleven of these, while a minute pair are to be detected upon the 12th; and on the 13th they are very much larger, and although they do not connect with the sternum, they possess fully developed uncinate processes. Next follow five dorsal vertebræ, each one possessing a perfect pair of ribs, which connect with the sternum by costal ribs; the last pair may be with or without uncinate processes, and if they be present, they are exceedingly small.

A slender pair of ribs also comes down from the first sacral vertebra; these never possess uncinate processes in *Sturnella*, and their slender costal ribs never reach the sternum.

. These vertebræ in the Meadow Lark have all the usual processes

conspicuously developed, with lofty neural crests upon the dorsal ones, and tricornuate hypopophyses upon the ultimate four or five cervicals. The median hypopophysial canal for the passage of the carotid marks the 5th, 6th, 7th, and 8th cervical vertebræ in *Sturnella.*

Several specimens of *Xanthocephalus xanthocephalus* which I have examined repeat exactly, both in regard to the number of the vertebræ and the disposition of their ribs in the cervico-dorsal region, what we have just found to obtain in *Sturnella.*

Agelaius phœniceus likewise enjoys precisely the same arrangement of these parts.

Typical Orioles, as *I. bullocki* and *I. spurius*, also exhibit the same condition.

In specimens of Brewer's Blackbird (*Scolecophagus cyanocephalus*) before me, I also find the same number (eighteen) of vertebræ, with the first free ribs on the 12th cervical, but in the case of the last dorsal pair of ribs, as well as the sacral pair, both may occasionally have their costal ribs reaching the costal borders of the sternum, where they articulate as do the true dorsal hæmapophyses.

Molothrus ater is the first form which I meet with that departs from this rule. In this species we find nineteen cervico-dorsal vertebræ, with the first free ribs on the 13th cervical; another well-developed pair, with uncinate processes on the 14th, then follow five true dorsals, whose ribs connect with the sternum by costal ribs, and finally a pair of sacral ribs which do not possess uncinate processes, nor do their hæmapophyses, as a rule, connect with the sternum.

Carefully counting these cervico-dorsal vetebræ in specimens of *Calamospiza melanocorys*, I find that it too possesses nineteen of them, and that the arrangement of the ribs is exactly as we have just found them in *Molothrus.* Very probably this will be the number found for all the typical Fringilline birds, and I predict it is the rule in *Dolichonyx.*

It points with no little significance to the Fringilline affinities of *Molothrus* over its Icterine claims.

Let us next turn our attention to this part of the skeleton in the *Corvidæ.* In a Raven I find that there are nineteen cervico-dorsal vertebræ, and that the leading eleven cervicals never support free ribs; the 12th usually possesses a very rudimentary

pair indeed; these are still better developed on the 13th, where they yet lack, however, the capitula. On the 14th the ribs are quite perfect, long, and still free, yet do not develop uncinate processes. The 15th vertebra in a Raven is a true dorsal, and to include the 19th these segments all connect by their ribs, through costal ribs, with the sternum. A pair of ribs, without uncinate processes, is also supported by the first vertebra in the pelvic sacrum, but their hæmapophyses fail to reach the costal border, on either side, of the sternum.

Here we see, then, in the *Corvinæ* we have a different plan of the cervico-dorsal region of the spinal column than we found to exist either in the *Icteridæ* or in the *Fringillidæ*.

This arrangement in *Corvus corax* will probably be true for all the typical Crows, in so far as this part of the spinal column is concerned, and of the pelvis and tail vertebræ we will speak further on.

Next we pass to a skeleton of *Pica*. Now *Pica* has precisely the same arrangement of its cervico-dorsal vertebræ and ribs as I have just described for a Raven and the Crows. This I could almost have predicted beforehand, from simply examining a skull of that bird. Moreover, the forms of the vertebræ in this Magpie, although smaller of course, are wonderfully like the corresponding ones as we find them in any typical Crow.

Carefully examining into this point in a number of skeletons of *Cyanocephalus cyanocephalus*, it was soon ascertained that this interesting species also agreed in this regard with the Crows and with the Magpies. There is one thing in all of these birds, however, we may often expect to find, and this is, that although the lateral canals in the 12th vertebra are *never closed* in them by the pleuropophyses, yet the diminutive pair of ribs may not always be liberated on both sides beneath the transverse processes of the vertebra. Sometimes one will be, rarely both, and often the pair remain anchylosed with the diapophyses.

Jays next command our attention. Judging from a number of species representing several genera of our typical United States Jays, the count goes to show that they also possess nineteen cervico-dorsal vertebræ, and that essentially the arrangement of the ribs is the same as we found it to be in the

Laterally, we observe an acetabulum surmounted by its anti-trochanter, both having the most usual ornithic form. The ischiadic foramen is rather large, of a subelliptical outline, and entire, by which I mean that it is distinct from any of the surrounding foramina, as in Carinate birds generally. The obturator foramen is small and circular, and between it and the large subelliptical "obturator space" the ischium meets the postpubis for a distance of some two millimetres to completely fuse with it at this point in the adult bird.

Posteriorly, the ischium again meets the postpubic rod, behind the obturator space, in a downward-turned foot-like process of some size, but anchylosis does not take place at this latter point. Directly behind this locality the postpubic element is rather abruptly turned upwards, and soon terminates in a sharp point.

Comparing this pelvis of *Sturnella* with the bone as we find it in a specimen of *Agelaius phœniceus*, I find them to be fashioned essentially upon the same plan; this is true also of *Xanthocephalus*, but in this latter genus it is not so rare a thing as to find that the ilia do not meet the superior margin of the sacral crista, indeed quite an interval may exist on either side, and the condition be present in 50 per cent. of the specimens. In both genera, *i.e.*, in *Sturnella* and *Xanthocephalus*, I should mention, the ilium, on the lateral aspect of the pelvis, notably overarches the ischiadic foramen, and the last-named genus the better displays this character.

In *Scolecophagus* it is the rule rather than the exception to find the ilia well separated on either side from the sacral crista, and these bones in this preacetabular region are in this species manifestly narrower than they are in *Sturnella*, in short, the pelvis of this Blackbird (*Scolecophagus cyanocephalus*) shows a marked tendency crow-wards; it still possesses, however, but *ten* sacral vertebræ, and the ilia are produced as processes posteriorly as we found them in the Meadow Lark, and are shown in fig. 7.

Never yet have I found any species of an Oriole (*Icterus*) wherein the ilia reach the sacral crista, and although the pelvis in this genus of birds is modelled upon the same plan as it is in *Sturnella* and the typical Marsh Blackbirds, it has nevertheless a facies peculiar to itself. *Icterus bullocki* possesses a pelvis far more like *Scolecophagus* than *Icterus spurius* does, and in both of these true Icterine birds the ischium meets the postpubis behind in a far more slender process than we found there in *Sturnella*.

As to *Molothrus ater*, its pelvis is almost distinctly Fringilline,

and, aside from a slight individuality of its own, departs but imperceptibly from the type of such a pelvis as we find in *Calamospiza*. The differential shading, however, as we pass in review from the pelvis of *Sturnella*, the true Marsh Blackbirds, and the Orioles into the typical Conirostral birds, of one *species* into its next most nearest ally in this particular character is, to say the least of it, very gradual.

Things wear a very different aspect when we come to examine the pelvis in the *Corvidæ*, for in the genus *Corvus* we find *eleven* (11) vertebræ fused together to form the pelvic sacrum, a number which I can determine with great accuracy from the pelvis of immature specimens of Crows and Ravens before me at the present writing.

In a pelvis of a Raven I find that the first *four* (instead of 3 as in *Sturnella*) sacral vertebræ throw out their transverse processes to meet the under surfaces of the ilia; then follow two more vertebræ with the uplifted and shortened diapophyses, and finally five ultimate ones which send out their processes to the mesial margins of the ilia in the postacetabular region.

The pelvis of a Crow (*C. americanus*) now at hand, has but four of the ultimate vertebræ which we have in the last mentioned, but the three preceding ones have the shortened uplifted diapophyses, and the total number is *eleven*, as in the Raven. On the present occasion I am unable to say whether or no this is the normal state for our American Crow, with respect to these vertebræ.

So far as I have examined them, "ileoneural canals" are invariably present in the pelves of Crows (fig. 5) and Ravens, the mesial margins of the ilia never meeting the sacral crista.

Parial interdiapophysial foramina, as a rule, exist only among the last few sacral vertebræ of the postacetabular area. Another difference we note between the pelvis of *Sturnella* is, that the extremities of the postpubic elements in the former are not abruptly turned up as they are in the latter, and are comparatively longer in the genus *Corvus*.

Pica pica hudsonica has a pelvis which is in all particulars the perfect minature of that bone as we find it in *Corvus corax*, and will need no further description here.

Fortunately I have by me the skeleton of a young *Cyano-*

cephalus cyanocephalus, and from it I am enabled to accu-
rately determine that *eleven* (11) vertebræ fuse together to
form its pelvic sacrum, and this holds good for the pelves in the
typical Jays, as *Cyanocitta,* and others in my collection.

Now the pelvis of a Jay (*C. stelleri*), and I have several of the
American genera of them thoroughly represented, has all the
general characteristics of the typical Corvine pelvis, while at the
same time it has a peculiar facies of its own, quite unmistakable,
yet almost defying exact description.

This Garruline character of the pelvis I find enjoyed to the
fullest extent by the pelvis in *Cyanocephalus.* To make my
meaning clearer I would say this: were it possible, for instance,
to have a series of say twenty pelves of Ravens before us, and
twenty each of thé pelves of *Cyanocephalus* and *C. stelleri,*
the latter forty being *brought up in the point of size* to those
of the Raven, I could, I think, without much difficulty assort
them into three lots correctly representing the three species.
But the most perplexing part of such a task would surely be
in properly deciding upon the pelves of the Jay and *Cyano-
cephalus;* the Ravens I could throw out at once,—so much do
the skeletons of allied existing birds resemble each other, espe-
cially in the individual bones.

The *caudal vertebræ* need not detain us very long. I find
six of them and a pygostyle to be the rule in *Sturnella;* the
same for *Xanthocephalus* and *Scolecophagus;* six again and a
pygostyle in *Agelaius,* in *Icterus,* in the Crows, *Cyanocephalus,*
and in the Jays, and finally in *Molothrus* and *Calamospiza;* so,
in so far as mere number is concerned, this does not count for
much, but by careful comparison of the actual forms of these
six vertebræ and their terminal pygostyle, as they are found in
the numerous skeletons representing the several groups and
genera just mentioned, I am enabled to state that in the main
they accurately support the differences which we found to exist
in the spinal columns and pelves, as already pointed out for
these several genera of birds,—as, for instance, they assume a
form more Fringilline in *Molothrus* than in any way Icterine
in that bird; and, again, these six vertebræ and the pygo-
style constituting the skeleton of the tail in *Pica,* bear a
closer resemblance to the corresponding part of the skeleton in

Corvus americanus than to the same parts, segment for segment, in the skeleton of the tail in *Cyanocitta stelleri.*

Sternum and Shoulder Girdle.

Our knowledge of the general form that the sternum assumes among the *Passeres* has long been settled, and this bone in the *Icteridæ* and *Corvidæ* is closely fashioned after the well-known pattern. In *Sturnella* the sternum is a comparatively large one for the size of the bird, and all of its usual Passerine characters are conspicuously developed. The manubrium is very prominent, and has a sharp anterior edge, with a flat surface posteriorly. It presents the usual bifurcation in front, and its main median part is considerably prolonged. Behind it, at its base, the coracoid bones meet mesially in the groove intended for their reception. Laterally, the "costal processes" of this sternum are lofty lamina-like projections of a quadrilateral outline. The body of the bone is oblong in form, exhibits a longitudinal, median, though shallow groove, from which the surface, on either side, of this thoracic aspect slopes up towards the lateral borders of the bone. The xiphoidal notches are deep, and the lateral processes they give rise to have expanded posterior extremities. Five hæmapophysial facets are found upon each costal border, the row, however, occupying in either case less than one-third of the total length of a lateral margin, not including the costal process. Beneath, the carina extends the entire length of the body of the sternum ; its angle in front is an acute one, and the lower margin of this keel is convex forwards, and finished off for its full length by a delicately raised rim.

Xanthocephalus possesses a sternum so much like *Sturnella* that it would be difficult to distinguish them, and in a mixed lot of say twenty of these bones from each species, I know of no character, even including the size, by which I could properly assort them again successfully. It is just possible that the median stork of the manubrium will average shorter in *Xanthocephalus* than it will in *Sturnella*, and the hinder moiety of the sternal body in the former species, will, as a rule, be found to be narrower. With respect to size of the sternum, either of these species may afford us examples of the bone which show a difference of some half a centimetre or more in

length, measured along the median longitudinal diameter of the body of the bone. I have in my collection two sterna of *Xanthocephalus* taken from adult specimens, both males, and one of them thus measured proves to be 3·2 centimetres long, and the other 2·7 only. In both species the sternum is non-pneumatic. This is also the case in *Scolecophagus*, a bird that likewise has a sternum of a pattern similar to *Sturnella*, and about one-third smaller in size. So, too, with *Agelaius*, where it is still smaller. Among the Orioles (*Icterus*) it is non-pneumatic, and although of the same general form as in the species just alluded to, it shows a marked decrease in its length, with a slight increase of breadth. In *Molothrus* all the essential characters are the same, but the bone has now so gradually shaded in the direction of the Finches, that it would be absolutely impossible to tell it from the sternum in some of the Conirostral birds possessing it of about the same size.

When the comparative morphology of our Passerine birds is better known than it is to-day, and the question of structure enters more extensively into classification, I predict that the sternum in this group will by no means afford one of the best distinctive characters at our command.

Ravens, Crows, Magpies, and Jays, indeed all our *Corvidæ*, have the sternum highly pneumatic, the orifices for the admission of air into the inner tissues of the bone being found down the median line upon its thoracic aspect; in the little concavities among the hæmapophysial facets on the costal borders; and finally, in the vast majority of specimens, of all species, at the base of the manubrium by a circular and always single foramen, situated in the middle line of the coracoidal grooves. This condition of the sternum in the *Corvidæ* seems at least to be one good character which it possesses, and is not enjoyed on the part of the sternum of the *Icteridæ*.

As for the general design of the bone, it remains the same in these Corvine birds as in the Passeres at large; when compared with an average Icterine sternum, however, it will be seen that the xiphoidal notches are not so profound, nor is the stem of the manubrial process nearly as long in comparison. These notches, taking the size of the bone into consideration, are shallower in *Corvus corax* than in any Jay (*Cyanocitta*) that

I have ever examined. *Pica* has a sternum which is absolutely the perfect miniature of that bone in *Corvus americanus*, while in *Cyanocephalus* and the Jays it is, indeed, difficult to distinguish it for the several species, and yet, as I say, in both groups the general facies of this bone is the same throughout.

Returning now to the subject of the paper, *Sturnella*, we will glance for a moment at the bones of its shoulder girdle. The coracoids in this bird have long and slender shafts, the sternal extremities of which are not notably expanded, while their summits present the usual Passerine characters, and afford the usual articular surfaces for the head of the os furcula, and the glenoid cavity of either shoulder-joint. A *scapula* possesses a blade in form resembling the blade of a miniature scimitar, while the bone anteriorly, in addition to making the usual articulations with the corresponding coracoid, sends forward a conspicuous clavicular head or process, against which, when *in situ*, the expanded extremity of the os furcula of that side rests.

Coming next to this clavicular element, the *os furcula*, we find it to be of the U-pattern, so commonly assumed among the Passerine birds. Its hypocleidium is of an irregular oblong outline, and, comparatively speaking, of an unusually large size. The scapulo-coracoidal heads of the os furcula are transversely flattened, and decidedly expanded. As already hinted, they rest, in each case, posteriorly against the clavicular process of a scapula, and externally against the summit of the corresponding coracoid. All three of these elements of the shoulder-girdle in *Sturnella* are absolutely non-pneumatic, a character which, I believe, obtains among the higher groups of the Passeres generally.

This bird, too, in common with other *Icteridæ* and *Corvidæ*, has a well-developed ossicle, an *os humero-scapulare* at the posterior aspect of its shoulder-joint.

Although these bones are of smaller size, and present a few minor variations of an individual nature, they are in *Agelaius* essentially what we have just found them to be in the Meadow Lark, and really require no special detailed description here. They are, too, non-pneumatic, air never gaining access to their interiors in this or the following genus.

Xanthocephalus likewise offers us a shoulder girdle almost the counterpart of the one we have just described above for *Sturnella*, and in nearly all particulars. The blade of the scapula in this Yellow-headed Blackbird, however, is markedly narrower than we find it in that genus, being of a somewhat different form too, with its apex posteriorly terminating in a

definite little point, which inclines slightly towards the median line. This rather unessential, though really distinctive character of the blade of the scapula in *Xanthocephalus*, I find to be a constant one for the species, and where the shoulder girdles of two such birds as those now under consideration are so wonderfully similar, any difference we can detect becomes of *some* value.

Scolecophagus also has the bones of its shoulder girdle completely non-pneumatic, and of the same essential character as in the foregoing species, smaller than, but otherwise very much as we find them in *Xanthocephalus*.

This general type of the shoulder girdle is also extended to the Orioles (*Icterus*), where it yet remains non-pneumatic, but in form more closely approaches the bones composing it as we find them in some of the higher Passerine groups, a difference, however, which would be exceedingly difficult to commit to words, unless we entered upon a detailed comparison of the most insignificant characters.

Molothrus ater has the same style of shoulder girdle as the Marsh Blackbirds among the *Icteridæ*, and yet can claim for it a certain peculiarity, an individuality of its own, which is an evident tendency Finch-wards, and we see its almost exact counterpart in such forms as *Pipilo* and *Calamospiza*.

Speaking then in general terms, we can say that the shoulder girdle of our United States *Icteridæ* possesses as a common character complete non-pneumaticity, and although there may be almost typically Conirostral birds in existence which could with little or no special violence wear the shoulder girdle of a *Sturnella*, still this truly Icterine representative has that part of its skeleton stamped with an individuality of its own, which nevertheless, as we come to consider it through the series of its nearest allies, including *Molothrus*, and still more likely *Dolichonyx*, gradually, and quite imperceptibly, grades into the form of the girdle as seen in the *Fringillidæ*.

In the *Corvidæ*, we soon find that the general character of the shoulder girdle is entirely different. In a Raven (*Corvus*), for instance, every bone in it is highly pneumatic, with large foramina present at their usual sites for the admission of air to their interiors. As compared with *Sturnella* we find that the

bones in the Raven when *in situ* are articulated pretty much in the same way, but in form they differ in having comparatively shorter coracoids, with stouter shafts, and more tuberous summits. The blade of a scapula is also comparatively shorter and vertically thicker, more especially as we pass in the direction of its head. But the most marked difference is seen in the os furcula, where the limbs are comparatively much stouter, though laterally compressed as are the coraco-scapular heads of this bone; and, finally, its hypocleidium is reduced to an almost insignificant and sharpened elevation, occupying principally the posterior aspect of the bone at its usual site when present.

This, as well as the rest of the skeleton of a Raven, I have fully illustrated by life-size figures in another connection, a work now in the hands of the Smithsonian Institution for publication.

As we would naturally expect to find it, the shoulder girdle in *Corvus americanus* is, except in point of size, being of course proportionally smaller, almost the counterpart of what we find in a Raven.

Passing next to our Magpie (*Pica*), we find that although the coracoids and os furcula are always pneumatic, the scapula is very often not so, and this latter bone has a somewhat different form besides, as its posterior extremity is always found to be abruptly and obliquely truncated. In the os furcula, the limbs are rounded and comparatively more slender than they are in Crows and Ravens, and the hypocleidium more prominent, while the tuberous summit of each coracoid presents anteriorly a peculiar little down-turned process which appears to be quite as characteristic as it is constant for this bone in the girdle of the Magpie.

Cyanocephalus also has the elements of its pectoral arch pneumatic, and while the general form of the coracoid, scapula, and os furcula is of a modified Corvine pattern, it has now nevertheless departed to a very appreciable extent from these bones in a Raven. The limbs of the os furcula are very slender, while the hypocleidium of this element has again assumed a size quite comparable with that process in *Sturnella*, being three times as big in proportion to the size of the bird as it is in a Crow.

Jays invariably possess an *os humero-scapulare* at the shoulder-joints. *Cyanacitta stelleri* has the shoulder girdle much as we find it in *Cyanocephalus*, the bones all being pneumatic, with the os furcula of the U-shaped variety, having a large hypocleidium directed backwards, the limbs slender, and the superior expanded extremities comparatively smaller than they are in *Corvus corax*, but articulated with coracoid and scapula in precisely the same manner as we found them in that bird. At the summit of each coracoid anteriorly, we find the same down-turned process as was noted in *Pica*. The sternal extremities of these bones are but moderately dilated, and when *in situ* touch each other in the coracoidal groove of the sternum. Over this point of tangency we sometimes see in this, and no doubt other Jays, a delicate osseous rod extending from the base of the manubrium to the middle point of the anterior sternal margin opposite. In a specimen of *Piranga ludoviciana* this little rod is quite a substantial osseous bridge, and I am inclined to think that it is a constant character in that species. If it be so it is a very pretty distinctive one for the Panagers, as all Passerine birds do not possess it by any means, and we all are aware how difficult it is to distinguish the sternum of the birds of this group in species of the same size, or nearly the same size.

The blade of the scapula in *C. stelleri* is rather long, and quite narrow, the posterior fourth being moderately truncated, obliquely from within outwards to the apex, the latter being finished off with a peculiar little pointed process.

Of the Pectoral Limb.

All of the bones in the upper extremity of *Sturnella* are non-pneumatic, and their lengths and calibres are harmoniously proportioned throughout the entire skeleton of the limb for a bird of its size. The *humerus* has an average length of 3·4 centimetres, and although of the usual Passerine form, has a peculiar individuality of its own. Upon first examining this bone we are struck with the unusual size of its pneumatic fossa, which is divided into two nearly equal concavities by a longitudinal lamina of bone. This unduly developed character lends marked prominence to the ulnar tuberosity of this humerus, a prominence which is not equally enjoyed by the radial crest, for that feature we find to be but feebly pronounced, and but slightly raised above the general superficies of the shaft of the bone. This latter is nearly straight, of a subcylindrical form,

being somewhat compressed in the same plane in which the proximal enlargement principally lies.   Distally, the extremity of this humerus presents us with all the usual ornithic characters there found on the bone in representatives of this group of birds.   The condyle on the ulnar side of the bone is notably produced in the same line with the long axis of the shaft, and constitutes rather a noticeable feature there, while a smaller process is to be found jutting from the condyle opposite the oblique tubercle on the radial side.

The skeleton of the pectoral limb is also non-pneumatic in *Agelaius*, a bird having a humerus which exhibits all the essential characters just attributed to the bone in *Sturnella*; it is, however, owing to the size of the species, smaller, and has a few unimportant features peculiar to itself.

Among the Orioles (*Icterus*) we note but little or no change in the general type of this bone, and which it assumes in the foregoing genera.

Xanthocephalus has a humerus very like the one we found in *Sturnella*, and, if anything, the spaciousness of its pneumatic fossa is still more striking, one of the divisions actually invading nearly the entire humeral head, the articular surface of which arches over the concavity.

In *Scolecophagus* we begin to notice a departure on the part of the humerus, slight though it be, as it gradually takes on the form of the bone as we find it among some of the higher groups of the Passeres, as the *Fringillidæ*, for instance; and this departure in that direction is still better marked in *Molothrus*, where the humerus has a form quite indistinguishable from some of the Conirostral birds of about the same size as this Cow-bird.

So far so good for the pectoral limb in the *Icteridæ*; we will return to it again when we come to consider the bones of the antibrachium and pinion.

Corvus corax offers us a humerus which presents the general features of that bone as it is found among the Crows and Jays, and the style of it is strikingly different from what we have just been considering in the *Icteridæ*.   In the first place it is *completely pneumatic*, although the fossa wherein the foramina are harboured is by no means as extensive in comparison, nor is it divided into two parts as we found it to be in the *Icteridæ*, and most, if not all, true Passerine birds.   On the other hand,

the radial crest is rather more conspicuous, while the shaft of the bone assumes the sigmoid curve for which it is noted in some other Avian groups. Its distal end presents the usual grooves for the passage of tendons; the oblique and ulnar tubercles; and a conspicuous process jutting from the external condyle at its proximal aspect.

True Crows (*Corvus*) all possess a humerus of this general type; and as for that matter, so does our American Magpie (*Pica*), which can claim but a difference in point of size, and were it possible to reduce a lot of humeri of Ravens to the similar dimensions of a lot of humeri of Magpies, it would be hard work to distinguish them. There is one character, however, which probably would not fail us in such a strait, for we find that the internal condyle is markedly produced, in the line of the shaft of the bone, beyond the ulnar tubercle in the Magpie, which is not the case in the Raven, but other than this feature I know of none which could at all be relied upon.

Cyanocephalus and the Jays all possess humeri of the same general pattern as the Crows, and in all the bone is highly pneumatic. Unfortunately, however, among these birds it really offers us no characters whatever of a true taxonomic value. Indeed, I have just been critically comparing a good series of humeri of several species of our typical United States Jays, with another series of the bone from numerous specimens of *Cyanocephalus cyanocephalus*, and I must confess there could be found absolutely no detail in character whatever by which I could with certainty distinguish them : and were a lot mixed up together before, I doubt my own ability, and I must believe it would be impossible for any one, to properly assort them again for the several species represented.

Both *Icteridæ* and *Corvidæ* had the bones of their antibrachia and pinions non-pneumatic.

Sturnella has an *ulna* which averages from 4 centimetres in length, and a *radius* of three and a half (3·5) centimetres. The former has an unusually prominent olecranon process, while the tubercles along its rather straight shaft, for the insertion of the quill-butts of the secondaries of the wings, are fairly well marked.

The radius, too, has a shaft which exhibits little or no curvature for the entire length of its continuity.

Radiale and *ulnare* bones are of the usual Passerine form in the carpal joint, and make the ordinary articulations with the long bones of the antibrachium and manus. In its hand we find the wonted number of segments; pollex digit having but one phalanx; index two; and annularis one; with a carpo-metacarpal element of the normal type. There are no claws upon any of these fingers. A good character to note in the carpo-metacarpus is, that the more slender element of this compound bone, the metacarpus to the annularis digit, extends, distally, some considerable distance beyond the main division of this segment of the hand. The proximal phalanx of the index digit develops a moderately expanded portion posteriorly, which here is level and smooth on the palmar side, but showing one long, even excavation on the anconal.

The skeleton of manus in this bird has a total length of 3·5 centimetres, measured from the summit of the carpo-metacarpus to the distal end of the index digit.

Xanthocephalus agrees in the main with the above description for the skeleton of its antibrachium and pinion, presenting but a few specific differences hardly worthy of notice, and these principally refer to the general lengths and proportions of the several bones. These remarks apply with equal truth to the genus *Agelaius*, where, of course, the bones are all very much smaller than they are in the Meadow Lark, as the bird itself is so much smaller.

Orioles (*Icterus*) present us with a very similar structure of the skeletal parts of the forearm and hand; we note, however, that the papillæ along the shaft of the ulna are entirely missing, and the several bones show a few other minor specific variations.

Scolecophagus agrees in the main with other American Icteridæ in this other part of the skeleton, which at the best offers us but few or no good taxonomic characters.

Molothrus ater has the bones of its antibrachium and pinion so much like the corresponding ones in these parts of some of the Finches, that I fail to find a constant and reliable character by which they may be with certainty distinguished from them. Yet at the same time they imperceptibly intergrade in resemblance to the Icterine forms in this particular, as this bird does in so many other structural respects. Nevertheless the skeleton of the arm in *Molothrus*, in its general appearance and actual form, is far more like the skeleton of the arm in an average Conirostral bird, a true Finch, than it is like the corresponding part of the skeleton in *Sturnella*.

As much as the humerus in a Raven differs in structural details from that bone in *Sturnella*, and really excellent distinguishing characters can be picked out upon comparison of the two, other than size, one would naturally expect to find a similar state of things extended to their forearms and hands; but such is by no means the case, for upon careful comparison, point by point, I detect no decided differences whatever between the two, in this part of their skeletons, and were the bones of the antibrachium and manus of an average specimen of *Sturnella* increased in proportionate size, so as to be equal in this respect to those of a Raven, they would surely be most marvellously alike.

Carefully comparing these parts in numerous specimens of *Cyanocephalus cyanocephalus*, *Cyanocitta cristata*, *C. stelleri*, *C. s. macrolopha*, *Aphelocoma woodhousei*, *A. californica*, *Pica p. hudsonica*, and others, I find that in the main the statement embodied in the last paragraph applies with almost equal truth to them. To be sure, if we lay out upon our study table nice clean specimens of series of the skeletal parts of the antibrachium and pinion of the several species mentioned above, we may, upon a general scrutiny of the entire lot, detect certain individual characteristics, only too difficult to commit to paper in order that the results of such a survey might be of any assistance, or a correct elucidation of the real affinities of these birds, but which convey to my mind, when taken in connection with what has gone before, the shadowings of the kinship of the species under consideration.

For instance, the parts in *Pica* more nearly resemble the corresponding parts in a Crow (*C. americanus*) than they do in a typical Jay, Woodhouse's Jay, we might say in illustration. Indeed, the true Jays have these bones all astonishingly similar, and *Cyanocephalus* agrees with them in this particular, but I will waive further discussion of these points here, and incorporate what we may learn from a study of this part of the skeleton, in the groups before us, in our final conclusions.

Of the Pelvic Limb.

From femur to ungual joints inclusive, all the bones in the pelvic limb of *Sturnella* are non-pneumatic.

Three (3) centimetres is about the average length of the *femur* in

this species, where the bone is seen to possess a subcylindrical shaft that is slightly bent so as to be convex forwards. The head of the bone is sessile with the shaft, and much excavated on top to form a pit for the insertion of the ligamentum teres. Beyond, and continuous with the head, we find the summit of the shaft occupied completely by the articular facet from the anti-trochanter; while the trochanter major itself does not perceptibly project above this latter surface, it is seen to do so anteriorly.

At the distal extremity of the bone, the two condyles are fashioned very much as we find them among Passerine birds generally. The external condyle is both the larger as well as the lower of the pair on the shaft; while posteriorly it exhibits the usual cleft for the head of the fibula, here quite profoundly sculpt. On the upper side of the internal condyle is developed a conspicuous osseous process, directed upwards, which is constant for this species, and which I propose to designate as the *epicondylar process* of the femur.

A large *patella* is present in this species, and is fashioned upon the most usual form of that sesamoid in Oscines, being, however, rather uncommonly broad and deep across and through the surface of its superior aspect.

Next we find that the *tibio-tarsus* has an average length of 5·4 centimetres, and the *fibula* about 3·4 centimetres.

The latter bone is long and slender, merging with the tibio-tarsus at its outer side, and upon the lower third of its shaft. Tibio-tarsus itself is a more than usually straight bone in the Meadow Lark, the shaft being nearly cylindrical in form, showing but a slight antero-posterior compression. At the proximal extremity the cnemial crest is considerably raised above the general articular surface of the summit, while the pro- and ecto-cnemial crests are conspicuously developed. They stand out abruptly from the shaft, while above their borders are continuous along the cnemial crest. Turning to the distal extremity, we note the presence, in front, of the usual little osseous bridge of bone, immediately above the condyles, through which the tendons pass in life, on this aspect; and the condyles themselves, which here offer us nothing worthy of special remark, as they are much as we find them in almost all Passeres.

Four centimetres is the average length of the *tarso-metatarsus* in the skeleton of the leg of *Sturnella*, where it assumes a form common to it in the vast majority of representatives of this great group of birds. Its hypotarsial apophysis is prominently developed, and of a cuboid form, being vertically pierced by fine tendinal foramina. Of these, the pair next the shaft, where they are placed side by side transversely, are by all odds the largest. Then posteriorly there is a small pair situated the same way, while between the inner one of these and the inner one of the pair next to the shaft, is found the fifth and smallest foramen of the group.

Distally, this bone has a large and freely articulated accessory metatarsal, and the pedal digits have the normal number of 2, 3, 4, and 5 joints to the first, second, third, and fourth toe respectively. Basal phalanx of hallux measures 1·6 centimetres, and its osseous

ungual claw 9 millimetres. Normally, the tendons at the back of the tarso-metatarsus ossify for nearly their entire length. Further, this bird is notorious in having a number of quite sizable osseous sesamoids located in the tendons of the foot. One, large and constant, is to be found between the trochlea and the proximal extremity of the basal joint in the inner of the three anterior digits. At least three others are to be found in the various tendons which glide in the sole of the foot, while a small one is usually found between the basal joint of hallux and the accessory metatarsal, in the tendon of the *flexor longus hallucis* muscle.

Aside from its rather smaller dimensions, and a few unimportant individual peculiarities, the pelvic limb in *Xanthocephalus* essentially agrees with that part of the skeleton as I have just described it in *Sturnella*. We may note in passing, however, that the epicondylar process of the femur in this Yellow-headed Blackbird is not as well developed as we found it to be in the Meadow Lark.

Among the Orioles (*Icterus*) this process seems to be entirely missing, and the skeleton of the pelvic limb in these birds, as compared with *Sturnella*, had a still more distinct character peculiarly its own. The pro- and ecto-cnemial processes of the tibio-tarsus are in it of a characteristic form, the outer one being a very sharp, downwardly-turned hook, approached in character by some of the Finches. *Agelaius* presents us with no special noteworthy departures from the common type in this part of its skeleton, nor do the Bronzed Blackbirds (*Scolecophagus*).

In *Molothrus* we see the general resemblance again with the *Fringillidæ*, though the essential features of the skeletal parts of the pelvic limb, even in this bird, are very much as we found them to be in *Sturnella*.

So far as I have examined them, the *Corvidæ* also have a pelvic limb, the skeletal part of which is completely non-pneumatic.

Not only that, but throughout this family it is plain to be seen that the bones comprising it are fundamentally the same in design and character as the corresponding bones in the *Icteridæ*. Even if you choose this limb of a Raven, so superior in mere size to the limb in *Sturnella*, we cannot fail to see that a certain type of structure is evidently common to the two. To be sure we shall find the *relative proportions* of the several bones considerably altered, and some few indescribable differences due

to specific peculiarities, but little or nothing which offers us strong tangible characters, pointing to valuable classificatory aids or distinctive differences.

As a rule, the epicondylar process is nearly entirely missing in the femora of these Crows and Jays, and in *Pica* I note in the hypotarsus of the tarso-metatarsus one of the posterior, perforating foramina is converted into a groove, but even this may not be constant. Sesamoids are not usually present in the feet of the *Corvidæ* as we found them so unusually developed in *Sturnella*; ossification, however, normally extends to the tendons of some of the muscles, especially the flexors, in these Corvine birds, as I have already stated to be the fact in the *Icteridæ*.

Final Discussion and Conclusions.

Presenting, as I have, throughout the present memoir simply a brief description of the most useful and essential characters in the several species of the two groups of birds under consideration, it will now only be necessary to recapitulate here some of the most important ones, and those which really seem to point to the true affinities of the species, in order that the reader may have them before him, as the writer invites his attention to the most important part of this paper, the conclusions which have naturally evolved from his researches.

To still further facilitate this matter, I herewith present a table, which gives concisely some of the important data culled from the body of the memoir, and so arranged that we may appreciate certain skeletal differences and similarities among the representations of our United States *Icteridæ* and *Corvidæ* at a glance. It will be unnecessary to offer any explanations for this table, as the data contained in it are, I think, sufficiently explanatory.

There is one thing in which I hope to be distinctly understood, and that is this,—in arriving at my conclusions as to the affinities of the several species we have had under consideration, it has been solely through my studies of the skeletons, and as their osteology seemed to indicate them. No one could be more averse to allowing taxonomy to rest upon any single set of characters, or even upon any particular system of the economy,

TABLE.

Species.	Free Lachrymal Bone in Adult.	Predominating *facies* of the Skull, and associated Parts of the Skeleton.	No. of the Cervico-dorsal Vert.	No. of Cervical Ribs, and which Vert. on.	No. of Dorsal Vert.; Sternal.	No. of Dorsal Vert. which have "Floating Ribs."	No. of Vert. in Pelvic Sacrum.	Caudal Vertebræ, not including Pygostyle.	Humerus; Pneumatic or Non-pneumatic.
Sturnella m. neglecta,	Yes.	Corvo-icterine,	18	12th, 13th,	5	1	10	6	Non-pneumatic; divided fossa.
Icterus spurius,	No.	Icterine,	18	12th, 13th,	5	1	10	6	Do.
Icterus bullocki,	No.	Icterine,	18	12th, 13th,	5	1	10	6	Do.
Scalecophagus cyanocephalus,	No.	Icterine,	18	12th, 18th,	5	1	10	6	Do.
Agelaius phœniceus,	No.	Icterine,	18	12th, 13th,	5	1	10	6	Do.
Molothrus ater,	No.	Ictero - fringilline,	19	13th, 14th,	5	1	10	6	Do.
Corvus corax sinuatus,	Yes.	Corvine,	19	12th, 13th,	5	1	11	6	Pneumatic, and undivided fossa.
Corvus americanus,	Yes.	Corvine,	19	12th, 13th,	5	1	11	6	Do.
Cyanocephalus cyanocephalus,	Yes.	Garruline,	19	12th, 13th, (varies.)	5	1	11	6	Do.
Pica p. hudsonica,	Yes.	Corvine,	19	12th, 13th,	5	1	11	6	Do.
Cyanocitta stelleri,	Yes.	Garruline,	19	12th, 13th,	5	1	11	6	Do.
Aphelocoma woodhousei,	Yes.	Garruline,	19	12th, 13th,	5	1	11	6	Do.
Calamospiza melanocorys,	No.	Fringilline,	19	18th, 14th,	5	1	10	6	Non-pneumatic, and divided fossa.

much as I have seen to support the fact as to the importance of the osseous system. True affinity of forms can only be arrived at through a correct appreciation of the *entire* structure of those forms after the proper comparisons had been made, and in many cases we are indeed fortunate if we arrive at the truth even then, for the gaps among existing types are sometimes very, very wide.

Upon carefully considering all the characters presented in the skeleton of *Sturnella m. neglecta*, I would say that it represents a genus which undoubtedly belongs to the *Icteridæ*; that within that family it probably has its nearest ally in *Xanthocephalus*, and its most remote one in such a form as *Icterus spurius*. Outside of its own family it finds its nearest relation probably in *Cyanocephalus cyanocephalus*, and I dare say that when *Picicorvus columbianus* comes to be structurally examined, there will prove to be a certain kinship there also.

The genus *Icterus*, I take it, represents the typical structural organisation of the family to which it belongs; and these, the true Orioles, in so far as our United States avifauna is concerned (and in no instance do I go beyond it here), see their nearest allies in the genus *Agelaius*, but they have, we must remember, an evident inclination Finch-wards.

Quiscalus I have not examined, that is recently, but am inclined to believe that it will be found to show a Corvine tendency in its skeleton, though it undoubtedly belongs to the *Icteridæ*, where this genus now is.

Molothrus is a genus of Finches, and as such should be placed in the family *Fringillidæ*, where it more properly belongs; and these Cow-birds undoubtedly see their nearest kin in such a genus as *Scolecophagus* among the *Icteridæ*. Here, no doubt, although I have not recently examined the form, *Dolichonyx* also belongs, and this last genus, I predict has a skeleton still less like a typical Icterine one than has the Cow-bird. Osteologically, *Molothrus* and *Pipilo* are not so very unlike.

Turning next to the *Corvidæ*, we find the family very properly divided into the *Corvinæ* (Crows, &c.) and the *Garrulinæ* (Jays, &c.). Undoubtedly the *Corvinæ* are typically represented, structurally and otherwise, by the genus *Corvus*. But why *Pica* should be considered a Garruline bird I cannot imagine;

so far as its skeleton is concerned *it is a Crow*, pure and simple; and I doubt not for a moment that the remainder of its economy will go to support this fact. From skull to toes the skeleton of a Magpie is the perfect miniature of the skeleton of our common American Crow (*C. americanus*), and quite unlike the skeleton of a typical Jay.

These latter are well characterised, osteologically, in the four genera *Cyanocitta, Aphelocoma, Xanthoura*, and *Perisoreus*.

Rarely do we find a better structural go-between, in the case of two subfamilies, than we see in the Piñon Jay (*C. cyanocephalus*); this genus I believe could be placed with either Crows or Jays indiscriminately, without more violence in one instance than in another. Further, it plainly shows in its skeleton, and skull especially, its remote kinship with *Sturnella*, and thus nicely links the *Icteridæ* with the *Corvidæ* at this point.

EXPLANATION OF PLATES XIV., XV.

[All the figures were drawn by the author from the specimens.]

PLATE XIV.

Fig. 1. Left lateral view of the skull of a specimen of *Sturnella magna neglecta* (× 2). *l*, lachrymal; *pp*, pars plana; *v*, vomer; *pl*, palatine; *pt*, pterygoid: *q*, quadrate.

Fig. 2. The same skull as shown in fig. 1, seen from above (× 2); lettering the same, with *ju*, jugal; *na*, nasal.

Fig. 3. Basal aspect of the same skull shown in the foregoing figures 1 and 2 (× 2); lettering the same, with *mxp*, maxillo-palatine; *eu*, Eustachian tubes, anterior entrances; *qj*, quadrato-jugal; *bt*, basitemporal; *oc.*, occipital condyle; 9, foramen for hypoglossal nerve; 8, foramen for glossopharyngeal and vagus nerves; *ic.*, foramen for internal carotid artery; *mx*, maxillary.

Fig. 4. Superior aspect of the mandible of the same specimen of *Sturnella ;* life size.

PLATE XV.

Fig. 5. Dorsal aspect of the pelvis of a specimen of *Corvus americanus ;* life size.

Fig. 6. Dorsal aspect of the pelvis of a specimen of *Pica pica hudsonica ;* life size.

Fig. 7. Dorsal aspect of the pelvis of a specimen of *Sturnella magna neglecta ;* life size.

Fig. 8. Right lateral view of a skull of *Pica pica hudsonica* ; life size from the specimen in the author's cabinet.

Fig. 9. Superior view of a skull of *Pica pica hudsonica* ; life size, the same specimen as in figure 8.

Fig. 10. Basal aspect of a skull of *Pica pica hudsonica* ; life size, and the same specimen as shown in figures 8 and 9. In figures 9 and 10 the mandible has been removed.

Fig. 11. Right lateral view of the skull of a specimen of *Xantho-cephalus xanthocephalus* (adult ♂, × 2) ; from a bird of this species collected by the author at Fort Wingate, New Mexico, July 1886.

Fig. 12. Right lateral view of the skull of a specimen of *Xantho-cephalus xanthocephalus* (adult ♂, × 2), from a bird of this species collected by the author in Wyoming (U.S.) in 1879. Figs. 11 and 12 are not only introduced in illustration of the osteology of the group of birds we here have under consideration, but to show also the marked individual variation that may take place in this part of the skeleton in birds of the same species.

July 1887.

THE PHARMACOLOGY OF THE NITRITES AND NITRO-GLYCERINE. By G. ARMSTRONG ATKINSON, M.D., *formerly Assistant to the Professor of Materia Medica, University of Edinburgh.*

ACTION ON STRIPED MUSCLE.

THE account of the general action has shown how powerfully this is affected. The precise effect was ascertained by removing the gastrocnemii, with their bony attachments, from deeply curarised frogs, and the muscles in normal saline were compared with those in normal saline containing nitrite of sodium. With 1 per cent. of nitrite of sodium the muscles ceased to contract to the strongest current in eleven minutes, with 1 in 1000 in about an hour, with 1 in 10,000 in about twenty hours.

Effect on Non-striped Muscle.—The intestines and ureters of rabbits were experimented with. For examination of the intestines the animals were killed by bleeding, two portions of the small intestine removed, and placed, one in normal saline, the other in saline containing nitrite, the experiment being conducted in a hot chamber at 100° F. With 1 of nitrite in 100, no contraction occurred with the strongest current in thirty to forty minutes; with 1 in 1000, in three to four hours. For the ureter experiments rabbits killed as above were kept in a hot chamber, and normal saline run through one ureter, while through the other saline containing nitrite was passed. Dilatation of a marked nature occurred with the nitrite, indicated by increased flow. Similar results were obtained by alternating normal saline and saline plus nitrite.

ACTION ON THE NERVOUS SYSTEM.

On Motor Nerves.—Owing to the rapid and marked paralysis of striated muscle by the nitrite, it is impossible to draw any very definite conclusions as to the effect of the poison on motor nerve endings. From the fact that in nerve muscle prepara-

tions laid in solutions of the nitrite, and in frogs not very profoundly affected, the muscle will contract to a weaker faradaic current applied to the nerve than to the muscle itself, and that the vagi terminations have been shown to be unimpaired until the animal was practically dead, it may be concluded that the action on the peripheral terminations of motor nerves, if any, is very slight. Strong solutions applied to the trunks of motor nerves do induce very marked paralysis; a 5 per cent. solution of nitrite of sodium in normal saline causing paralysis in less than an hour. Saturated watery solutions produce muscle twitching when applied to the nerve trunks, probably due to the coarse chemical action of the salt. The nerve with such a solution rapidly becomes paralysed. Solutions of 1 in 100 have almost no effect. Such a mode of investigation seems to me of very questionable value, however. To ascertain if any action occurred on motor trunks in the body, the femoral artery in frogs was ligatured about the middle of the thigh, and the animal then poisoned. After death the nerve was stimulated as high as possible, and found to be of normal excitability.

On Sensory Nerves.—Solutions of 5, 10, and 20 per cent. were painted over one posterior limb of frogs; the femoral artery in the painted limb being first ligatured high up, and the whole limb, except the sciatic nerve, then ligatured high up, to avoid absorption of the nitrite as far as possible.

Comparisons made as to sensibility between the painted and unpainted limb gave no evidence of the production of any anæsthetic effect. Solutions applied to the nerve trunks paralysed the sensory fibres much as in the case of the motor nerves, but here again the method may be held of very doubtful value.

On the Spinal Cord.—The general phenomena of poisoning would point to paralysis of all the functions of the cord, although many of the cord symptoms might be accounted for by the effect of the nitrite on muscle.

Experiment.—To eliminate this possible fallacy, the femoral artery and then the whole limb, except the sciatic nerve, was ligatured high up in frogs, and the poison then subcutaneously injected. The diminution of reflex action in the ligatured limb occurred much less

rapidly than in the unligatured. No preliminary stage of increased reflex activity could be detected. The reflex functions in both the ligatured and unligatured limbs became gradually diminished, or altogether abolished, according to the dose. When quite abolished in the ligatured limb, stimulation of cord between scapulæ produced tetanus in ligatured limb, with a stronger current than before administration of the nitrite, but no movement, even on direct stimulation of the muscles, could be obtained in the unligatured. An example with a large dose may be given.

June 30. Frog. 30 grams. Left femoral and then whole limb, except sciatic, ligatured at 1.10,

1.20. Electrodes applied to skin between scapulæ produced at 100 tetanus in both limbs. Four grains nitrite of sodium subcutaneously injected. Reflex movements gradually weakened, and at 1.40 no reflexes in unligatured limb, and feeble in ligatured. Sciatic nerve in unligatured limb exposed, and when current at zero applied, feeble movements, both in unligatured and in ligatured occurred; in the latter case, of course, the movements were reflex.

1.45. Stimulation of sciatic in unligatured limb only produced slight movement in ligatured. Stimulation of cord at 100 produced tetanus in ligatured limb, but even at zero none in unligatured.

1.50. No movement in ligatured limb on stimulating sciatic of unligatured, and very strong pinching of ligatured limb caused only feeble movement of toes, which could not be obtained at 1.55, and tetanus only obtained by current of 80 to cord.

2.15. Current to cord has gradually required to be increased, until now at zero tetanus only is obtained.

2.30. No tetanus; only feeble movements of toes on stimulating cord at zero. Stimulation of sciatic in ligatured limb at 350 produced vigorous muscle contraction.

In a series of frogs the brain was destroyed, the cord exposed, and solutions of nitrite of sodium applied. This, if saturated, produced some preliminary irritation, followed by a rapid paralysis. A 20 per cent. solution produced no symptoms of irritation, but merely progressive loss of function, the solution being too weak to produce course chemical action, and requiring to be absorbed to produce its action. A frog weighing 41 grams required current at 110 at 10.45 to exposed cord to obtain limb movements. At 10.47 a 20 per cent. solution of the nitrite applied to cord. At 10.54 current required to be increased to 90 to obtain same amount of movement. At 11.10 current 40; at 11.40 at zero. Sciatics normally excitable.

Moreover, as showing an affection of the conducting power of the cord, it was observed in both frogs and mammals that the posterior extremities were somewhat more affected than the

anterior at an early stage of the poisoning. No special experiment was made to ascertain the effect on sensory conduction, but it would appear from the experiments given in various connections that the whole cord is generally paralysed; and it is evident from the above, that while the muscles are paralysed before the cord, the cord has its reflex action rapidly markedly diminished, while its conducting power is much more slowly interfered with.

On the Brain.—Owing to the effect on the cord and on the muscles, it is difficult to ascertain whether the brain is depressed or not. From the general action it would appear so to be, and also from analogy with the cord. If the frog's brain be exposed, and a strong solution, as 20 per cent., applied to it, slight symptoms of irritation, followed in twenty to thirty seconds by depression of function, are produced. The depression is very pronounced in from two to three minutes.

On the Amount of Urine and its Constituents.—The examination of the effect on the amount of urine, and on the excretion of urea and uric acid, was made in large bitches kept in proper cages, and the urine measured at a certain hour, the animals being catheterised, and any urine obtained added to that in the vessel used to collect the day's urine. The animals were kept on a strictly uniform diet, and not used for any experiment until they were in a state of nitrogenous balance.[1] I have elsewhere shown that small doses of nitrite of sodium either did not affect the amount of urine, or it sometimes increased it slightly, sometimes diminished it. Large doses always diminished it. The urea and uric acid excretion were practically unaffected. With small doses nitrites were not always excreted by the urine. When two or three grains, however, were administered, the reactions were almost invariably present. In no case was any albumen found, nor was any sugar present unless almost fatal doses were administered, and the action kept up by repetition of the dose. Numerous experiments on rabbits were made, in order to ascertain if glycosuria could be induced. It was ascertained that, in order to obtain

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[1] For details I must refer to my paper on "The Influence of the Nitrite Group upon the Urinary Constituents," read at the Dublin meeting of the British Medical Association, 1887, and shortly to be published in the *British Medical Journal.*

sugar in the urine, it was necessary to administer the nitrite in almost toxic doses, and keep the animal profoundly under the influence of the drug; then, after three and a half to four hours as a rule, sugar was abundantly present in the urine. If the exhibition of the drug be then stopped, in a few hours more the sugar had quite disappeared. Coincidently with the appearance of the sugar, the flow of urine, which had previously been markedly diminished, very considerably increased.

The Excretion of Nitrite of Sodium and its Fate in the System.

This is an exceedingly interesting question.

Röhmann (*Zeits. f. phys. Chemie*, v. pp. 233 and 94) states that nitrites are never found in the urine when it is fresh, and Hoppe-Seyler (*Handbuch*, 5th ed., p. 356) quotes Schœnbein, to the effect that the urine contains no nitrous acid until it becomes muddy from acid fermentation; while later, with the alkaline fermentation, it loses the nitrous acid. This nitrous acid has been believed to be from reduction of nitric acid, and it has also been believed to be due to the oxidation of ammonia. Röhmann shows conclusively that no nitrite is formed in decomposing urine by the oxidation of ammonia, and he considers it to be always due entirely to the reduction of nitrates present in the urine. He shows, moreover, that no nitrite or nitrate is formed in the system normally except from pre-existing nitrite or nitrate; and points out that, although with a vegetable diet the urine does usually contain traces of nitrates, with a milk, white bread, or flesh diet, or in starvation, nitrates entirely disappear from the urine. Bence Jones (*Phil. Trans.*, 1851) failed to find nitrates normally in the urine, but his method does not seem to me satisfactory. To estimate the nitrates the Schultze or Schlœsing method, with ferrous chloride and hydrochloric acid, is probably the best to use, as it gives very accurate results with nitrate free urine to which definite quantities of nitrates have been added. With nitrites the method gives results below the truth, and in my experience very variable results, probably due to decomposition occurring between the freed nitrous acid and urea. Nitrites in the urine (for that they do occur has been mentioned already) are best estimated by one or other of the colorimetric methods, such as the starch and iodide of potassium. Even here a small loss of nitrite occurs, not due to the urea or uric acid, but apparently to the colouring matters of the urine. The loss is extremely small, however.

The urine of man, of the dog, and the rabbit was examined for nitrites and nitrates. Nitrite of sodium, when administered

to rabbits, even in fatal doses, is very rarely found in the urine, but nitrates were always present, although, of course, the animal was on a diet which gave no nitrates. Röhmann has shown that the nitrate obtained from the urine is much less than corresponds to the nitrite administered, and the results of my experiments so closely coincide with his observations that it is unnecessary to give more than a single example.

Experiment, 21st Feb. 1887.—Rabbit, 4¼ lbs., kept from 13th Feb. on milk diet, received one grain of nitrite of sodium subcutaneously at 11 A.M., at 1, 3, and 5 P.M. ; total, 4 grains = 202·7 milligrams of nitric anhydride (N_2O_5).

Urine of 20th Feb. contained nitric oxide equal to 0 milligrams nitric anhydride; of 21st, equal to 0; of 22nd, equal to 67 ; of 23rd, to 24; of 24th, to 4 ; of 25th, to 0 ; total, 95 milligrams.

In this experiment the fæces were carefully examined for nitrites and nitrates, but they contained none. The urinary passages, then, are the channels by which alone the nitrite as such, or as nitrate, can pass off. Therefore in this experiment a loss of nitrite in the system to the extent of 53·1 per cent. has occurred. What becomes of the unaccounted-for nitrite will be discussed immediately. Nitrites have been found in the saliva and also in the perspiration, but no loss could occur in the rabbit by these sources. It has been mentioned that no nitrite is usually found in the urine of rabbits. It is readily enough obtained in the urine of dogs. In these latter animals the excretion begins very shortly after its administration, and continues with doses of 2 or 3 grains subcutaneously for twenty-four to thirty-six hours. The more vigorous the dog is, the less readily is the nitrite detected. The same holds in man, men in vigorous health rarely having nitrite reactions in their urine even after very considerable doses, while patients in bed give it comparatively readily. If the urine be very acid, obviously the analysis ought to take place as rapidly as possible.

It seems reasonable to assume that in rabbits, since the blood always contains nitrites after death, the drug is present in the urine, but in too small a quantity to be detected. It is obvious from the above that, while a large portion of the nitrite is excreted as nitrate, a considerable, and in many cases the principal, portion of it is destroyed in the system. The nitrite

which is excreted as nitrate probably becomes this salt in the blood, for peroxide of hydrogen in alkaline solution can readily convert nitrite into a nitrate, and in the blood oxygen is present in a condition presenting many analogies to one of the oxygen atoms in the peroxide of hydrogen molecule. Further, since in the various organs of the body various reducing processes occur, and as there is no definite proof that any nitrogen, as such, is excreted by the lungs beyond that absorbed from the atmosphere, it is justifiable to presume that the loss of nitrite is most probably due to its partial conversion into ammonia and then into urea. The amount of urea so produced is too small to appreciably augment the amount excreted.

It is held, as stated, that nitrates are reduced to nitrites in the urine after evacuation by the acid fermentation. Urine containing nitrates undoubtedly when exposed to the air in a few days contains nitrites, but I have always found the nitrates appear only when the urine is becoming less acid, due to commencing alkaline fermentation. Sterilised human urine containing nitrates, but no nitrites, was inoculated with various bacteria, and the growths thus cultivated. With such bacteria as the *Bacterium termo* and the *Micrococcus ureœ*, the urine copiously contained nitrites, but the urine was strongly alkaline, and after being kept for months still contained nitrites in undiminished quantity. When the *Bacillus butyricus* was cultivated no nitrite was obtained. Therefore, nitrites are developed in urine containing nitrates, with the alkaline, and not with the acid fermentation, and they do not disappear as the alkaline fermentation progresses.

We will now briefly discuss some other nitrites, viz., nitrite of potassium, nitrite of ethyl, and nitrite of amyl, pointing out any important differences in action from nitrite of sodium.

Nitrite of Potassium.—The only paper of importance on this salt is by Reichert, which has already been referred to. He states the salt produces restlessness and excitement in frogs, followed by depression and inco-ordination of voluntary movements, clonic convulsions or a tetanoid condition being occasionally present. Convulsions were seldom observed in mammals, and are described as cerebral. Motor and sensory nerves are mentioned as being depressed, and the blood pressure is stated as being primarily increased and then diminished.

I am unable to agree with these statements. Nitrite of potassium, according to the above account, seemed to differ in so many particulars from nitrite of sodium, that its action was fully investigated and compared with that of nitrite of sodium, from which it was found to differ in *no* particular. Nitrite of sodium contains 55 per cent. of nitrous anhydride; nitrite of potassium, 44·7. A lethal dose of nitrite of potassium will probably be a little higher than that of the sodium salt, the potassium element not quite counterbalancing this. No difference, however, was detected.

Nitrite of Ethyl.—In 1857 Brown (*Pharm. Jour.*) described some of the symptoms produced by inhalation of spirit of nitrous ether, namely "a ghastly, dirty pallor, and loss of muscular power," symptoms probably due entirely to the nitrite of ethyl in the spirit. Richardson (*op. cit., Med. Times and Gazette*, 1870, ii. 469, and *Med. Chir. Rev.*, 1867, p. 259) states that this nitrite in its action closely resembles nitrite of amyl.

My investigations into its action were mainly to ascertain how it differed from nitrites of sodium and amyl. The ether is very rapidly fatal, and frogs and rabbits both died in a few minutes when allowed to inhale the concentrated vapour. Subcutaneous injections also quickly killed.

In frogs, after subcutaneous injection, death occurred in a few minutes without any excitement, the reflexes becoming rapidly abolished. The blood, after death by inhalation or subcutaneous injection, was markedly chocolate-coloured. The heart was dilated. There was much feeble movement as compared with the normal frog on stimulation of the exposed cord. In one frog before inhalation, current at 120 between scapulæ caused tetanus ; directly after death, current at 80 required. Stimulation of the motor nerves or muscles readily induced muscular contraction, although the muscular irritability was very slightly impaired. The inhalation produced the same phenomena, except that the frog was at first very restless, apparently from the irritating effect of the nitrite on its mucous membranes. The effect of this nitrite on frogs, apart from the greater action on the central nervous system and the less on the muscular, was largely as with the sodium salt, no important differences being present. In rabbits, by inhalation, violent convulsions resembling those of ordinary asphyxia occurred, the animal after three or four minutes becoming quiet, with feeble respiratory movements, and rapidly dying. The *post-mortem* appearances were as with nitrite of sodium, except that muscle and motor nerve stimulation produced almost unimpaired muscular contraction. If, when respiration obviously failed in rabbits, the animal were left alone, death rapidly occurred. If

artificial respiration were employed, it speedily recovered. Sub-cutaneous injections in rabbits produced the phenomena of nitrite of sodium poisoning, except that, if a large dose were given, asphyxial convulsions occurred; and, further, death could be induced by a dose of 3 to 4 minims of the nitrite in five or six minutes. The nitrite, owing to its extreme volatility (boiling at 18° C.), was used mixed with twice its bulk of ethylic alcohol; and at the seat of injection after death, although there was a slight smell of alcohol, there was none of ethylic nitrite. In its effect upon the urine, this nitrite and the spirit of nitrous ether resembled nitrite of sodium. Owing to the necessity of admixture with alcohol, and to its own properties, intravenous injections of this nitrite were not carried out.

Nitrite of ethyl, therefore, while resembling nitrite of sodium in many of its actions, has a much more rapid influence upon the central nervous system and upon the blood than nitrite of sodium. The muscular system is almost unaffected. In these respects it approaches nitrite of amyl, but is much more rapidly fatal, both when inhaled and especially when injected sub-cutaneously, owing to its greater volatility, and the readiness with which it is soluble in the blood, in which partial decomposition of the nitrite rapidly occurs with the production of some metallic nitrite. It does not to any great extent cause suffusion of the face, and death (as with nitrite of amyl by rapid inhalation) is due to the action on the blood and the nervous system, the muscular being partially unaffected.

Nitrite of Amyl.—The literature pertaining to this nitrite is enormous; and only a very brief summary of it will be given. Guthrie (*op. cit.*) in 1859 first pointed out its peculiar effects in dilating the arterial system of the head and neck. Richardson, in his papers already referred to, states that the drug lessens muscular contractility, dilates the capillaries of the frog's web, and paralyses nerves from the periphery to the centre. Moreover, he states that amyl is the keynote in producing the action. Since Richardson's papers a host of observations have been published. Pick (*Centralb. f. die Med. Wiss.*, 1873, p. 865) and Ladendorf (*Berl. Klin. Woch.*, No. 43, 1874) have pointed out that objects look yellow to persons fully under the drug; and Pick, both in this paper and in a pamphlet (Berlin, 1874), showed that if one fixes the eye on a clear wall and inhales this nitrite, the point looked at becomes yellow, with a blue violet ring around it, and winding lines again end this. This appearance is probably caused by the projection of yellow retinal spot surrounded by its complementary colour (violet). Poisonous doses in man by inhalation have produced symptoms closely allied to those of nitrite of ethyl. In the lower animals, if the drug be pushed by

inhalation, as in a rabbit, the animal after violent struggles (apparently purely dyspnœic) becomes progressively weaker, reflex action being much diminished. Death occurs with inhalation quietly if the drug be not rapidly pushed, with asphyxial convulsions if it be. The heart continues to beat for a short period after respiration ceases. Immediate *post-mortem* shows little interference with muscular contractility, but very considerable with the functions of the central nervous system, just as with nitrite of ethyl, and the blood is markedly chocolate coloured. Frogs show, after death from rapid inhalation, much the phenomena observed with nitrite of ethyl. When subcutaneously injected, I have never observed convulsions, even previous to death. The animal merely gradually becomes very depressed, and dies quietly in a period varying very much according to the dose and rate of absorption. The nitrite of amyl employed was freshly prepared, and contained 80 per cent. of actual nitrite. Rabbits, weighing 3 or 4 lbs. after subcutaneous injection, gradually became very depressed, presenting all the phenomena of nitrite of sodium poisoning, but the phenomena generally required from 15 to 20 minutes to markedly develop, and even after the injection of 15 or 20 minims of nitrite of amyl, death does not occur for two or three hours, or sometimes not until after a much longer period. Rigor mortis is well marked. The *post-mortem* appearances resemble those with nitrite of sodium, but muscle irritability is never so complelely lost as with nitrite of sodium. There is usually a strong smell of nitrite of amyl on section at the seat of injection, and the tissues in the neighbourhood of the injection are of a yellowish-green colour and somewhat inflamed. No nitrite, no sugar, and no albumen is found in the urine in rabbits. In dogs, after administration of nitrite of amyl by the stomach, nitrites are found in the urine : not after inhalation, however, unless the animal be kept profoundly under the influence of the drug for many hours. The absence, after subcutaneous injection, of convulsive seizures before death is due to slow absorption. With nitrite of ethyl the rapidity of absorption, as was pointed out, allows convulsions to be produced. When the period before death is prolonged, after subcutaneous injection, to many hours, ecchymoses in the gastric mucosa are common, but not in the rapidly fatal cases. Experiments on the blood and circulatory system showed the same phenomena as with nitrite of sodium in most particulars. Methæmoglobin was somewhat more rapidly produced. The effects on the heart of the frog were precisely similar to those with nitrite of sodium, and Williams' apparatus gave the same results as nitrite of sodium. Gaspy (*Virchow's Archiv*, vol. lxxxv. p. 301) states that dilatation of both arteries and veins occurs on inhalation ; while Amez Droz (*Arch. de physiol.*, 1873, p. 467) considers there is almost no venous dilatation, but I obtained in frogs both arterial and venous enlargement. Attempts were made to pass nitrite of amyl solution through pithed frogs as described under nitrite of sodium, but the solutions too rapidly became acid from decomposition of the ether to allow any accurate observations to be made, and the same objection, but to a greater extent, held with

nitrite of ethyl. In mammals Kobert (*op. cit.*) has shown that blood containing nitrite of amyl, passed through their viscera in the manner described under nitrite of sodium, produces marked vascular dilatation. The cause of the vascular dilatation is much disputed. Berheim (*Pflüger's Archiv*, vol. viii. (1873), p. 283) states that the dilatation is due solely to an action on the central vasomotor mechanism ; while Mayer and Friedrick (*Arch. f. Exp. Path. v. Pharm.*, v. p. 55) consider the action local. Amez Droz considers it due to muscle paralysis. Brunton (*Jour. of Anat. and Phys.*, vol. v. p. 92) concludes it to be local paralysis of muscle or nerve. There can, I think, from what has been said, be no doubt that the nitrite affects the muscle, and it almost certainly depresses the vasomotor centres throughout the body, local and central. The ophthalmoscopic appearances produced by nitrite of sodium were considered in some detail. Aldridge (*W. Riding Asyl. Reports*, vol. i. p. 71) has described those produced by nitrite of amyl as being a deepening of the capillary tint of the disc, a doubling in size of the small arteries, and but little or no change in the veins, but Pick (*op. cit.*) denies this.

The experiments I carried out on dogs and rabbits gave precisely similar results to those obtained with nitrite of sodium. Effects on blood pressure are precisely analogous to those produced by nitrite of sodium, and also on respiration, except that from the rapidity of action on the blood when inhaled, nitrite of amyl can induce asphyxial convulsions. In connection with the subject of vascular dilatation, it is of interest to note that Pick has recorded experiments showing that when one inhales nitrite of amyl the vascular dilatation diminishes as you proceed from the head towards the feet, an easily confirmed observation. On temperature the same results as with nitrite of sodium were obtained. Striped muscle is not absolutely paralysed, but is very markedly impaired in contractility when a rabbit is poisoned by subcutaneous injection ; when killed by inhalation the muscle irritability is almost unaffected. In cases where the poison is directly applied to the muscle, either by placing the muscle in the nitrite or in its vapour, complete paralysis of the muscles rapidly occurs. Watery solutions were not used, owing to the ready partial decomposition of the compound when dissolved in water. Non-striped muscle, as of the intestine, gave similar results. Motor and sensory nerves, so far as could be judged by experiments allied to those with nitrite of sodium, were not affected. The spinal cord and brain apparently are affected much as with nitrite of sodium when the

amyl compound is subcutaneously administered, much as with nitrite of ethyl when given by inhalation. But the cord is much more affected, even after the subcutaneous injection of amyl nitrite by the amyl compound, in proportion to the muscles than occurs with nitrite of sodium, and probably the same holds with the brain.

The effects on the urine and its constituents were identical with those of nitrite of sodium, but the nitrite is by no means readily to be obtained in the urine, and but very little of it is converted into nitrate, the greater part passing off by the lungs. The well-known action of nitrite of amyl in producing glycosuria was first published by Hoffmann in 1872 (*Reichert and Du Bois Reymond's Arch.*, p. 746), but from some unpublished notes of experiments by Rutherford and Gamgee, which Professor Rutherford allowed me to read, it is evident that in 1867 they discovered this property of nitrite of amyl. Hoffmann's results are too well known to require repetition. My experiments gave a general confirmation of his results, but as a rule I found that sugar was present in the urine for not more than a few hours, unless nitrite of amyl was again injected. With inhalation the sugar appeared only after five or six hours, the animal being kept well under the influence of the nitrite the whole time. Nitrites of ethyl and amyl therefore kill when inhaled chiefly by paralysing the nervous system, and by their rapid action on the blood,—nitrites of sodium and potassium acting much more powerfully on the muscular system. Nitrite of amyl when subcutaneously injected doubtless partly becomes converted into a metallic nitrite, and hence acts more powerfully on the muscles than when merely inhaled. Nitrite of ethyl as mentioned also becomes probably certainly partly a metallic nitrite. To ascertain if the amyl could produce glycosuria, it may be stated that some experiments both by inhalation and by subcutaneous injection were carried out with acetate of amyl, but with negative results. Great dyspnoea was induced with this drug by both methods of procedure. As certain observers, notably Gaspy, have recorded experiments in which nitrite of amyl was intravenously injected, some examination of this method was made, with most unsatisfactory results, coagulation of blood invariably occurring to some extent, and the results were considered valueless.

The Pharmacology of Nitro-Glycerine.

From the consideration of the nitrites, we pass to this body, apparently so closely allied in its actions.

Sobrero ascertained it to be a poison, but he did not investigate its action. Many other experimentalists ascertained that the drug administered to rabbits and cats produced convulsions of a more or less tetanic nature followed by death. Pelikan (op. cit.) in 1858 showed that the drug given to rabbits, cats, or dogs produced tetanus and death, the post-mortem appearances being general hyperemia with ecchymoses in the mucous membrane of the stomach. Pelikan administered the poison in drops, which are extremely small, so that it is difficult to ascertain how much was really given. Other observers have confirmed and expanded these results. The most important researches are those of Brunton and Tait (St Bart. Hosp. Reports, 1876, p. 140), of Murrell (Nitro-glycerine in Angina Pectoris, 1882), and of Hay (Practitioner, June, 1883). Brunton and Tait showed that in frogs the subcutaneous injection of an alcoholic solution caused restlessness and tetanic convulsions. They believe the tetanus to be due to an action on the optic lobes. Cats receiving the same alcoholic solution intravenously also had convulsions. They further ascertained that it was a muscle poison, that it paralysed the cord, that it reduced blood pressure, that it stopped the excised frog's heart, and that it produced a chocolate colour in the blood just as nitrites do. They moreover state that, like nitrites, it quickens the blueing of guaiac. This latter point I doubt both with nitro-glycerine and nitrites. Murrell showed that sphygmographic tracings after nitro-glycerine resembled those after nitrite of amyl, and also stated from experiments on a patient with epispadias, that it caused a considerable increase in the urinary flow. Hay states that the action of nitro-glycerine is essentially similar in kind to that of a simple metallic nitrite, it however differing in intensity, $\frac{1}{100}$ grain producing often a more violent impression on the organism than two to three grains of nitrite of sodium, both being given per orem. Hay points out that nitro-glycerine when digested thirty to forty minutes with cat's blood at 40° C. produces methæmoglobin, and on dialysation of such blood he obtained nitrite reactions. He further states that the activity of nitro-glycerine is due to the nitrous acid which is formed by its decomposition within the body, and gives as a probable explanation of its great pharmacological power, as compared with nitrite of sodium, two factors—the absence of decomposition, and no loss of nitrite in the stomach, which occurs with nitrite of sodium, and the production of nascent nitrite in the system.

In man, nitro-glycerine has in several instances been the cause of accidental death, the symptoms recorded being severe headache, vomiting, occasional purging, perspiration, stupor, and failure of respiration. In small doses, when given to man, the

unpleasant headache produced is well known, the headache varying much in character. Syncope has sometimes occurred in man after large or even medicinal doses, just as after nitrite of sodium, and due as with this nitrite almost certainly to the fall in the blood-pressure the ether produces. The effects on the pulse, as shown by the sphygmograph, are identical with those of nitrite of sodium and of nitrite of amyl. They are more rapidly produced than with nitrite of sodium, but less rapidly than with nitrite of amyl. Its effects last longer than the effects of either the amyl or sodium salt. The explanation of this will be seen as we go on. The nitro-glycerine used in the following experiments was prepared in the ordinary way by myself; and in all cases either the pure drug was employed or a 1 per mille watery solution, previous observers having only used alcoholic solutions, and so introducing a source of fallacy.

GENERAL ACTION ON FROGS.

Experiment. March 1.—Frog, 20 grams. Temperature of room, 62° F.

- 2.36. 30 minims watery solution nitro-glycerine injected under skin of back—equals $\frac{3}{100}$th grain.

2.37. Frog began to walk slowly about, and refused to jump unless strongly irritated, when it sprang somewhat feebly, landing rather heavily. The spring was high, but only advanced the animal a short distance.

2.38. Frog allows itself to be pushed along some distance before it jumps. Movements stiff, and tendency for animal to rotate on its haunches. Respiration apparently unaffected. Reflex movements diminished.

2.39. Reflex movements very decidedly diminished.

2.40. Animal gave a sharp cry, and after a few seconds of very irregular movement, during which it threw, as it were, its limbs in all directions, its back being arched concavely and the mouth opened and shut several times, the frog passed into very profound tetanus, the lower eyelids being kept half closed. The tetanic spasm lasted about 40 seconds, the animal being left in a relaxed condition, but every attempt on its part to swallow air was attended by a slight tetanic spasm. A like spasm was produced by striking the table on which it lay, and a more violent by pinching a toe. The cutaneous vessels were somewhat dilated.

2.55. Reflex movements exaggerated, and on pinching strongly, feeble tetanic spasms occurred. The respirations somewhat slowed.

3.0. Well-marked tetanus produced if frog strongly pinched or lifted up.

4.30. Much as above.

5.0. Animal able to move a little without tetanus occurring, but tetanus still readily induced on pinching.

8.0. Animal moves posterior limbs more freely, but it only moves anterior to a very slight extent. Tetanus induced by strong irritation.

March 2.—11.0. Frog sits in ordinary position, but is somewhat lethargic. It does not jump readily, and often walks away if irritated. If it jumps it lands rather heavily with its limbs semi-extended. Reflex movements are feeble, respiration normal or slightly slowed. It can only turn off its back with difficulty.

6.0 P.M. Less feeble, but otherwise in much the same condition. It gradually improved, but was not quite normal until the 5th day. When smaller doses of nitro-glycerine are administered the tetanic condition is less marked, and with much smaller is absent, the irregular clonic movements alone occurring—$\frac{1}{160}$th of a grain, for example, in a frog weighing 20 grams will induce tetanus in ten or twelve minutes, but $\frac{1}{200}$th of a grain does not, the animal only taking clonic convulsions after eight or ten minutes, these lasting only a few seconds, and recurring occasionally for 20 minutes or so, from which period recovery gradually occurs. If large doses be given, the phenomena follow very closely those already described. A fatal dose to a frog of 30 or 35 grams is about 100 minims of watery solution, equal to $\frac{1}{10}$th grain. Tetanus occurs again and again, the attacks gradually becoming feebler, and death occurs in eight or nine hours after the injection. The *post-mortem* appearances are quite allied to those with nitrite of sodium. Respiration ceases some considerable time before the heart, the blood becomes of a chocolate colour, and spectroscopically shows methæmoglobin bands, and on dialysis yields nitrite reactions.

The convulsive phenomena points very strongly to a central origin. The movements before convulsions occur have been described as stiff. If the frog's limbs at this stage are moved the motion is felt to be stiff, as though the muscles were being kept semi-contracted—intervals of absolute remission of these symptoms being present. To ascertain if any of the phenomena were purely muscular, the sciatic nerve was divided high up on one side, and nitro-glycerine then injected. The limb with the cut nerve was quite unaffected. The animal otherwise presented the usual phenomena. Further, the femoral artery and then the whole limb except the sciatic, were ligatured high up on one side, and nitro-glycerine injected. The phenomena were identical in both limbs except that at a late stage of the poisoning the spasms were slightly stronger in the ligatured

limb, due almost certainly to the effect of the nitrite produced by the decomposition of the nitro-glycerine on the muscle of the unligatured limb in a way afterwards to be pointed out. To ascertain the seat of the convulsions, portions of the brain in frogs were successively removed, and the animals allowed to recover from the shock of the operations. Frogs from which the cerebral lobes alone, or frogs from which the cerebral lobes, the optic lobes, and the cerebellum, were removed, showed the convulsive phenomena just as before; but when medulla was removed the clonic convulsions were much less pronounced, and no rotatory movements occurred. The tetanus, however, is equally well marked. It is evident, therefore, that while the tetanus is due apparently entirely to an action on the spinal cord, the clonic movements, while to a slight extent produced by an action on the cord, are chiefly due to an effect on the medulla. The rotatory movements are entirely caused by an action on the medulla. In mammals tetanic convulsions occasionally occur when the drug is administered by the stomach, but very rarely according to my experience. Rabbits and dogs usually exhibit merely the phenomena of nitrite poisoning,—the phenomena coming very slowly on. Rabbits from 3 to 4 lbs. received from 1 to 6 grams of nitro-glycerine, and after slowly exhibiting the usual phenomena of nitrite poisoning, died quietly in from four to twenty-four hours. The animals which lived more than eight or nine hours usually had glycosuria, and the urine contained in all cases nitroglycerine freely. Nitro-glycerine could easily be obtained in the urine two or three hours after administration, and be readily extracted by ether. The *post-mortem* appearances were precisely those of nitrites, but the blood contained both nitrites and nitro-glycerine. 50 c.c. of the watery nitro-glycerine solution were given to rabbits by the mouth, and the dose repeated three or four times in the course of a few hours, without death occurring, or any symptoms beyond those of moderately well marked nitrite poisoning. As much as 22 c.c. were injected subcutaneously, and as much as 100 c.c. thrown into the peritoneal cavity. In no case was there ever any convulsive movement, only phenomena similar to that with nitrite of sodium. Very small doses, however, intravenously injected produced very pronounced clonic, followed by tonic, convulsions.

The injection of $\frac{1}{2}$ a c.c. $= (\frac{1}{2000}$ gram) would produce slight clonic movements in a rabbit of moderate size. The injection of 2 c.c. caused very pronounced clonic movements. With 5 c.c. these movements were followed by tetanus, and with 25 c.c. the tetanus was generally sufficiently severe to cause death; 40 to 50 c.c. invariably killed the animal. If only 15 or 20 were slowly injected the animal, after the tetanus passed off, made a good recovery if the wound were stitched up. For some minutes after the injection of such a non-fatal dose, when tetanus had ceased, imperfect tetanic spasms could be induced by tapping the animal. When the large doses were administered, the tetanus continued for about two minutes, the muscles became then quite relaxed, the animal breathed deeply two or three times, and then died. The *post-mortem* made immediately showed no abnormal phenomena, the muscles reacting readily to the electric current, and the blood being of normal colour.

Before discussing the phenomena, a brief statement may be given as to the action of nitro-glycerine on the individual systems.

On the blood and circulatory systems the phenomena are identical with those produced by nitrite of sodium, for, as Hay has shown, nitro-glycerine in the system rapidly becomes broken up into nitrites and other compounds, 100 parts of nitro-glycerine outside the body in alkaline solutions (and probably in the body likewise) yielding 33·48 parts of nitrous acid. No methæmoglobin could be detected after adding nitro-glycerine to blood until the blood gave, when dialysed, at the same time nitrite reactions. The action on the frog's heart, *in situ*, was examined in feebly curarised frogs so as to avoid the convulsions; the effects were precisely those of nitrite of sodium, and the same held with the vagus terminations, with the capillaries, with the arteries and veins. On the blood pressure analogous results were obtained, but very much smaller doses were required to produce a very marked fall. With Williams' apparatus similar tracings to those with nitrite of sodium were recorded, but with much weaker solutions; with 1 of nitro-glycerine in 1500 of blood and saline the pressure rapidly fell, and death of the heart in full diastole occurred in 10 to 13 minutes; with 1 in 20,000 no rise occurred; with 1 in 50,000 a slight rise was obtained,

corresponding very much with that from 1 in 10,000 of nitrite of sodium.

The same apparatus as with nitrite of sodium was employed to measure the outflow from the vessels in pithed frogs, and each minute's outflow was tested for nitrites. Marked increase of flow occurred with all degrees of dilution up to 1 of nitro-glycerine in 1,000,000, and in all cases up to 1 in 100,000 after a few minutes nitrites were found in the outflowing fluid, dilatation commencing apparently at once. Probably, when one used solutions weaker than 1 in 100,000, the amount of nitrite in the outflowing fluid would not be more than 1 in many millions, and thus be too minute for detection, although the starch iodide test is applicable to 1 of nitrite of sodium in some 15 or 20 million parts of distilled water.

Blood pressure experiments on rabbits gave exactly similar results to those with nitrite of sodium, the nitro-glycerine being administered in watery solution by subcutaneous injection. The vagi were unaffected as to their peripheral terminations, and section of the vagi, of the depressors, and clamping of the carotids gave results identical with those obtained with nitrite of sodium.

Respiration and *temperature* are affected just as with nitrite of sodium, unless the poison were intravenously injected, when convulsions occurred as described.

The effects on *striped muscle* were tested in the same way as with nitrite of sodium, using normal saline and normal saline with nitro-glycerine, this latter solution being tested every few minutes for nitrites, after the muscle was placed in it. A 1 per mille solution of nitro-glycerine caused complete paralysis in four to five hours, but in twenty to thirty minutes after immersion of the muscle nitrites were found present, and the effect is presumably due entirely to the nitrite produced.

Non-striped muscle was examined as in the case of nitrite of sodium with very similar results; results here again apparently due to nitrites and not to nitro-glycerine as such.

Action on the Nervous System.—Motor and sensory nerves were examined, as in the case of nitrite of sodium, with negative results.

The *spinal cord and brain effects* have been partially discussed,

but a few words more may be said. The severe headache nitro-glycerine produces in most persons, even frequently in those who for long have worked with it, is partly due to the nitrite produced, but also, I think, partly to a special action of nitro-glycerine, as no dose of nitrite of sodium will produce the intensely painful headache nitro-glycerine causes. It has been noted that there is, especially in frogs, a depression before the exaltation of reflex action even in brainless frogs. This depression might be explained by the production of nitrite, the nitro-glycerine action being a purely stimulating and tetanising one on the cord; probably, however, nitro-glycerine itself depresses before it exalts reflex excitability, although even with the smallest doses which would produce any pharmacological effect, depression of reflex action was always followed by exaltation. The seat of the convulsive phenomena has already been dwelt upon.

Effect on the Urinary Secretion.—Murrell has been quoted for his case of increased flow in an epispadiac; but all my experiments gave precisely similar results to those with nitrite of sodium, any dose above a very minute one always causing diminished flow of urine, and minute doses causing sometimes increase, sometimes diminution in the amount. The urea and uric acid were practically unaffected except that large doses of nitro-glycerine diminished the water, so that rather less urea and uric acid on the whole were eliminated by the kidneys. The production of glycosuria in rabbits after large doses of nitro-glycerine has already been referred to. Nitro-glycerine can readily be extracted after large medicinal doses from the urine of man, as previously noted, and very easily after large doses to rabbits, &c. Ether is the best extractive, and the nitro-glycerine can be decomposed by alkalies into nitrite, &c., and the nitrites estimated. From the blood nitro-glycerine is obtained by the same ether process.

The fate of nitro-glycerine in the system is obviously chiefly a conversion of it into nitrites, &c., and their subsequent changes. Partly it is excreted as nitro-glycerine by the urine. After poisonous doses per orem, it is usually to be found in the stomach, and in the upper part of the small intestine. Further on in the canal conversion of nitro-glycerine to nitrite, &c., occurs, and none is usually in the large intestine, unless a purgative be

administered soon after the poison. Under such circumstances, the fæces contain nitro-glycerine.

In the action of nitro-glycerine there arises the question—Why is it so difficult to induce convulsions in mammals except by intravenous injection ? It might be held that the rapid conversion of nitro-glycerine into nitrites by the action of the living tissues, and also by the chemical action of the blood, caused a nitrite action on the cord and brain, depressing them, and so interfering with the convulsive action of the nitro-glycerine. In connection with this theory, it may be stated that a saturated aqueous solution of nitro-glycerine, kept at 100° F., and mixed with a saturated solution of bicarbonate of sodium, gives nitrite reactions in about an hour, but if phosphate of sodium be used, in twenty to twenty-two minutes. The living tissues, however, as we have seen, very rapidly dissociate the ether, and to test the theory both frogs and rabbits received almost lethal doses of nitrite of sodium, and when fully under the influence of this drug nitro-glycerine was injected—subcutaneously in frogs, intravenously in rabbits—in every case tetanus was induced. It would appear, therefore, that the explanation is as follows :— Nitro-glycerine, although rapidly absorbed, is yet only absorbed in minute quantities, owing to its insolubility; the absorbed nitro-glycerine is partially at once broken up as indicated, while part is excreted by the kidneys if the dose be at all large. The nitrite produced, moreover, depressing the circulation, retards absorption, and there is no accumulation in ordinary circumstances of sufficient nitro-glycerine in the blood to cause convulsive movements. Two rabbits, each weighing 3½ lbs., were taken. One received 6 grams of nitro-glycerine by the stomach, and died in five hours, with the ordinary phenomena of nitrite poisoning. Immediately after death the blood was collected and the nitro-glycerine in it extracted, and $\frac{1}{350}$ gram obtained. The other rabbit received intravenously 25 c.c. 1 per 1000 watery solution of nitro-glycerine. This produced fairly well marked tetanus. The carotid of the opposite side was at once cut, the blood collected, and $\frac{1}{100}$ gram nitro-glycerine obtained. This, then, would indicate that the just-stated theory is the correct one as regards the usual non-development of convulsions.

Nitrite of sodium, therefore, is a purely paralysing agent, with the exception of the slight preliminary rise with small doses in the excised frog's heart, and the same holds in regard to the other nitrites examined. The differences in action between the different nitrites have been sufficiently pointed out in the discussion of them. Nitro-glycerine, on the other hand, as such, is a convulsive agent, its effects being masked by the decomposition it undergoes, and its therapeutical applications are due to the production of nitrites from it. The nitrite group does not, as Reichert especially would indicate, cause any rise of blood pressure at the commencement of the action in mammalia, but a steady fall, with marked acceleration of the heart-beat. This acceleration seems to be due, from the experiments given, principally to depression of the medullary inhibitory centre from fall of blood pressure, the peripheral terminations of the vagus being unaffected. It would also seem that the accelerating centre is thrown into action. The fall in blood pressure is obviously chiefly due to vascular dilatation, but at a later stage of the poisoning to a directly paralysing effect on the heart muscle, and also probably on the cardiac ganglia. The other points in the action of the group and of nitro-glycerine require no further elucidation. In conclusion, it may be stated that while nitrite of sodium or of potassium, and nitro-glycerine in watery solution as a 1 per mille solution, are suitable for administration by the mouth or subcutaneously, nitrite of ethyl and the spirit of nitrous ether are for exhibition by the mouth or by inhalation; while nitrite of amyl ought to be given by inhalation only, as its subcutaneous injection causes considerable pain and uneasiness, and if given by the stomach it requires to be in an emulsion, which allows considerable decomposition to occur.

Some experiments were made with digitalis and its preparations as an antidote in nitrite poisoning, but neither the administration of digitalis before or after the nitrites made any difference in the time of death.

THE MORPHOLOGY OF THE VAGUS NERVE. By
Thomas W. Shore, M.D., B.Sc., *Lecturer on Comparative Anatomy at St Bartholomew's Medical School.*

To understand properly the morphology of the vagus, we must obtain a knowledge of it in its simplest forms, by studying its anatomy and development in the lowest vertebrates. I will deal with the subject of this paper by summarising the leading features in the anatomy and development of the vagus in the Elasmobranch fishes, and in *Petromyzon,* which is the lowest type in which a vagus, in the ordinary acceptation of the term, is found. I will then state briefly the important modifications in the anatomy and development of this nerve, as seen in higher vertebrate types, and finally enter into the question of the morphological value of its parts, and whether anything equivalent to it is to be found in Invertebrata, and, if so, what?

Anatomy of the Vagus in Petromyzon.—The nerve arises from the medulla by four roots. These roots have the same appearance as the posterior spinal roots. They pass into a ganglion, from which are given off dorsal and ventral rami, as in the ordinary spinal posterior root. A branch which passes from the ganglion of the 7th nerve round the ear capsule joins the vagus ganglion at the point where the dorsal ramus is given off, and from this same point the " ramus lateralis " takes its origin. The dorsal branches of the posterior spinal roots pass over the " lateralis," and *send branches to it.* The dorsal ramus of the vagus passes to the skin of the posterior part of the head. The main vagus trunk continues backwards ventrally to the " lateralis," but dorsally to the gill slits, and gives off six branchial nerves to the six posterior slits. Both the anterior and posterior spinal roots send branches to it, each branch from a posterior root entering the nerve separately from the anterior root branch. There are, according to Ransom and Thompson,[1] from whose paper this account is mainly taken,

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[1] " On the Spinal and Visceral Nerves of Cyclostomata," *Zoolog. Anzeiger,* No. 227, p. 421, 1886.

ganglion cells in the vagus trunk, and these have roughly a segmental arrangement. The fibres which enter the vagus from the anterior spinal roots are large, and pass almost immediately to the muscles of the gill slits. Those which enter from the posterior spinal roots are small, as also are all the fibres contained in the main vagus roots from the medulla. There are in addition some very small fibres, which pass off as visceral nerves to the heart, &c.

Development of the Vagus in Petromyzon.—According to Shipley,[1] the first part of the vagus to appear is its ganglion. This arises, in common with the ganglion of the 9th nerve, *as a mass of cells split off from the epiblast*, close behind the auditory capsule. This mass is a large structure, and at first has *no root of connection with the brain*, nor with a similar cellular mass which forms the ganglion of the 7th nerve. The nerve roots arise subsequently, he believes, from a neural ridge. At a later stage he finds that the vagus is a longitudinal cord, upon which are six ganglia, each situated just in front of, and dorsally to, a gill slit, and supplying the gill slit behind which it lies. He does not appear to have traced the origin of these posterior ganglia, nor of the longitudinal trunk. He also states that he is unable to trace the nerve behind the posterior or 7th cleft, and has not found any trace of a "ramus lateralis" even in his oldest larvæ. The first or main ganglion lies between the first and second myomeres, and there is apparently no trace of the dorsal commissure described by Balfour in Elasmobranchs; nor does each ganglion appear to have a separate root, as is the case in Elasmobranch fishes.

The Vagus in Elasmobranchs.—In *Scyllium* the vagus arises by many roots, which join together into a single trunk. Soon after leaving the skull it gives off a dorsal branch, which supplies the skin in the occipital region. It next gives off a " lateralis " branch, which runs dorsally down the trunk, deeply seated between the dorsal and ventral systems of muscles. In its course the lateralis gives off long branches, which pierce the intermuscular septa to reach the sense organs of the lateral line. The main trunk then continues along the dorsal side of the branchial region, and gives off four " branchial " rami, each of

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[1] "On some Points in the Development of *Petromyzon fluviatilis*," *Quart. Jour. Mic. Sci.*, vol. xxvii. p. 325, 1887.

which forms the posterior branchial nerve, gives off an anterior branchial branch, and is distributed to the musculature of the corresponding slit. Where the branchial branch gives off the anterior branchial, *there arises a small pharyngeal ramus.* After giving off these branches, the main trunk continues onwards as the " visceral" nerve, supplying the heart, stomach, &c. In *Raia* the general arrangement is the same, but the " lateralis" is not given off so high up, and the branchial nerves thus take origin from the main vagus trunk before it has divided into the lateral and visceral branches. In *Hexanchus,* which has six gill slits, we find five branchial branches. In other respects the arrangement is similar to that of Scyllium and Raia, the lateralis branch being given off high up. The ordinary roots of the vagus are regarded by Gegenbaur[1] as the dorsal roots corresponding to what may be called the " vagus metameres," whilst two or three little roots which arise from the myelon-cephalon, beneath the vagus roots, are considered by him to be the corresponding ventral roots. These leave the skull separately, and are distributed partly to the muscles and partly join the anterior spinal nerves. Whether these are really anterior roots of the same meaning as the anterior roots of the spinal nerves we will not discuss here, but it may be remarked that, if so, then the corresponding dorsal roots differ from dorsal roots of spinal nerves in containing both motor and sensory fibres.

Hubrecht[2] mentions that one of his pupils has traced the " ramus visceralis" up the main trunk of the vagus as a bundle of fibres distinct from the branchial branches. For an account of the generally accepted views of Gegenbaur that the vagus is a compound of the dorsal roots of several " segmental" nerves, the reader is referred to the original paper.[3]

Development of the Vagus in Elasmobranchs.—In Scyllium there are formed, behind the ear, and in front of the first myomere, five nerves which develop as outgrowths from the neural

[1] *Elements of Comparative Anatomy,* English translation, by Jeffery Bell, p. 520, 1878.

[2] "The Relation of the Nemertea to the Vertebrata," *Quart. Jour. Mic. Sci.,* vol. xxvii. p. 638, footnote, 1887.

[3] " Ueber die Kopfnerven von Hexanchus und ihr Verhältniss zur Wirbeltheorie des Schädels," *Jenaische Zeitschrift,* B. vi., 1871.

ridge of the hind brain. The foremost is the glossopharyngeal; the posterior four form the vagus. Each of these five nerves possesses a ganglion, and is continued downwards to the posterior margin of a gill slit, giving off a slender branch to the anterior margin of the slit. At an early stage these five post-auditory nerves have two longitudinal commissures,—a dorsal one, which is probably derived from the neural crest, and can be traced backwards to the dorsal root of the 1st spinal nerve; and a ventral one, situated just beyond the ganglia, and which subsequently appears, according to Balfour,[1] to be continued backwards as the " visceral " branch. The " lateralis " branch is also said by Balfour to spring from this ventral commissure; and he regards it as being a dorsal branch of the main vagus stem, whose extension backwards has been due to the gradual elongation of the lateral line. Balfour does not appear to have obtained the earliest condition of the vagus in Elasmobranchs, for both Van Wijhe [2] and Beard [3] describe it as being at first a broad uninterrupted outgrowth, *exhibiting no evidence of segmentation.* According to them, at the stage when the gill slits are forming, the single root passes downwards, and fuses with a longitudinal thickening of epiblast lying just above the four posterior slits. Subsequently, according to Beard, an anterior part of this epiblastic thickening separates and forms the ganglion of the most anterior root of the vagus. The rest of the thickening forms one large ganglionic mass for the remaining vagus roots, but shows an indication of a division into three on its ventral aspect. Three branchial branches arise from this large ganglionic mass, and one from the smaller anterior ganglion. During the process of separation of the anterior ganglion from the epiblast, the rudiment of a " branchial sense-organ," and of a " dorsal " or, as Beard prefers to call it, " supra-branchial " nerve, are formed as special developments of the epiblast. Along with the separation of the posterior ganglionic mass from the epiblast, the epiblastic thickening from which it arose begins

[1] *Comparative Embryology*, vol. ii. p. 376, 1881. See also *A Monograph on the Development of Elasmobranch Fishes*, 1878.

[2] " Ueber des Mesodermsegmente und die Entwicklungsgeschichte der Nerven des Selachierkopfes," *Königliche Akad. v. Wiss. zu Amsterdam*, 1882.

[3] " The System of the Branchial Sense Organs, &c., in Ichthyopsida," *Quart. Jour. Mic. Sci.*, 1885.

to extend backwards along the lateral surface of the trunk, displacing the ordinary epiblast cells as it does so. This is the commencement of the " lateral line." The lateral nerve is formed by a separation of this thickening into two parts, the deeper of which becomes the nerve; it is thus seen to be formed *by a separation* in loco *of epiblast cells from the whole longitudinal extent of a surface thickening*, and not in the manner supposed by Balfour.[1] This mode of origin of the " lateralis " was first described by Semper [2] in Elasmobranchs, and by Goette [3] in Bombinator, and has been confirmed by Van Wijhe [4] and Beard.[5] Each of the elementary nerves of which the vagus-compound is said to be made up, is thought to contribute to this lateral branch; it is, in fact, regarded by Beard as the representative of the whole of the " dorsal " branches of the hinder of the vagus elements, and the lateral line is considered to be a compound of several " branchial sense-organs." Whilst the " dorsal" branch of the first ganglion and the " lateralis," as well as the ganglia, arise directly from the external epiblast, the *" branchial" and " visceral" branches have not this origin, but are formed from the original nerve root.*

Anatomy and Development of the Vagus in Rana.—In the adult the vagus arises by a root common to it and the glossopharyngeal. It leaves the skull just behind the auditory capsule, and dilates into a ganglion, beyond which the glossopharyngeal and vagus separate. The latter gives off a dorsal branch to the skin of the occipital region; the rest of the distribution of the nerve is visceral, the first branch being the laryngeal; then succeed cardiac, gastric, pulmonary, &c., branches. There is in the adult no lateralis nerve, nor any " branchial" branches, though these are both present in the embryo, the former supplying a " lateral line." The development of the cranial nerves, including the vagus, in the Frog, has recently been studied by Baldwin Spencer,[6] who shows that

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[1] " Development of Elasmobranch Fishes," *Jour. of Anat. and Phys.*, vol. xi. p. 407, 1877.

[2] " Das Urogenital System d. Selachier," *Arbeiten a. d. Zool. Zool. Instit. Würzburg*, vol. ii., 1875.

[3] *Die Entwicklungsgeschichte der Unke*, Leipzig, 1875.

[4] *Loc. cit.*   [5] *Loc. cit.*

[6] " On Some Points in the Early Development of *Rana temporaria*," *Quart. Jour. Mic. Sci.*, vol. xxv.; Suppl., p. 123, 1885.

no neural ridge, comparable to that of Elasmobranchs and Chick, is present, and that the nerve does not arise from the central nervous system, but is formed by a proliferation of the nervous layer of the general epiblast along certain lines. These subsequently separate, and acquire connections with the brain. The ganglion of the vagus arises as *one* large mass directly from the epiblast. The lateral line and nerve are formed as in Elasmobranchs. The results are confirmed by Beard,[1] but from the observations of Miss Johnson and Miss Sheldon [2] a neural ridge appears to be present in the Newt.

The Vagus in Amniota.—As compared with the condition in fishes, the vagus presents the following peculiarities:—

(1) The "ramus lateralis" is entirely absent. Huxley [3] thinks it is "represented only by small branches distributed chiefly to the occipital region." These, which appear to be the "auricular" nerve of human anatomy, are, I think, more probably equivalent to the "dorsal" branch found in Elasmobranchs.

(2) Owing to the absence of gills and the early disappearance of the branchial slits, the corresponding branches of the vagus, so characteristic of fishes, have either disappeared or else become converted into the pharyngeal and laryngeal branches, though it is doubtful to what extent this has occurred.

(3) Speaking generally, the part of the vagus of fishes which has been preserved and specialised in the Amniota is the "visceral" branch. The œsophageal, gastric, and anterior intestinal regions of the alimentary canal, as in fishes, receive branches from the vagus. The air-bladder in those fishes which possess one is supplied by offshoots from the visceral ramus, and this is preserved in Amniota by the distribution of filaments to the lungs.

(4) According to Gegenbaur,[4] the hinder portion of the roots of origin of the vagus in the Selachii become united into a small nerve trunk which forms the "accessorius" of Willis. This nerve appears to be foreshadowed in the Teleostei, in which a few of the posterior roots of the vagus unite into

[1] *Loc. cit.*, p. 117.

[2] "Development of Newt," *Q. J. Mic. Sci.*, vol. xxvi., 1886.

[3] *Anatomy of the Vertebrated Animals*, p. 71.

[4] *Elements of Comparative Anatomy*, English translation, p. 522.

a small nerve distributed to the muscles of the shoulder girdle.

(5) The inferior roots which are found in the area of the vagus origin in Elasmobranchs form a special nerve—the hypoglossus. Therefore, whilst the branchial and lateral branches tend to disappear, the visceral part and the rest of the nerve remains, and, according to Gegenbaur, forms three nerves—vagus, accessorius, and hypoglossus.

Development of the Vagus in the Chick.—The nerve arises with the glossopharyngeal as a common outgrowth from the neural ridge of the posterior part of the hind brain behind the auditory capsule. This was first shown by Marshall.[1] Very soon the common outgrowth splits into two, and the roots lose their connection with the neural ridge, like the posterior roots of the spinal nerves. As seen in a 122 hours' chick, the nerve runs obliquely downwards and backwards, and has a large ganglion lying over the third and fourth slits. Beyond the ganglion the nerve continues as an intestinal or visceral branch. Neither in this paper nor in his subsequent account[2] on this subject does Marshall describe anything comparable to, or which he identifies with, the "ramus lateralis" of fishes.

Marshall holds that the vagus root which he describes is morphologically equivalent to a posterior root of a spinal nerve. He further describes[3] "a number of small outgrowths from the ventral surface of the brain close to the median line on either side, ... separated by a considerable interval from the roots of the vagus. In appearance, position, and relations these small paired outgrowths are precisely similar to the anterior roots of the spinal nerves, to which I believe them to be strictly equivalent." He had not succeeded in tracing their ultimate fate, and does not explain how what he regards as posterior roots of the vagus come to contain both motor and sensory fibres. Balfour believed that they form the hypoglossal nerve, and are the anterior roots of *spinal* nerves, whose posterior roots have disappeared.

[1] "On the Early Stages of Development of the Nerves in Birds," *Jour. of Anat. and Phys.*, vol. xi., 1877.

[2] "The Development of the Cranial Nerves in the Chick," *Quart. Jour. Mic. Sci.*, vol. xviii., 1878.

[3] *Quart. Jour. Mic. Sci.*, p. 38, 1878.

We must now approach the question—What is the morphological value of the various portions of the vagus nerve ? The leading characters of this nerve, as shown by its anatomy and development in the types above considered, are—

1. Its distinction into two parts, viz.; the " lateralis " branch, and the " visceral " branch. With the lateralis branch we associate the ganglion, which arises in close connection with it, and, in the same manner, viz., as a *separation from the general external epiblast along a definite laterally placed line.*

2. Associated with the visceral branch, there is in fishes a definite series of branchial rami, which are distributed to the posterior gill slits in a manner comparable with what is believed by Marshall [1] and others to be the original mode of distribution of the 3rd, 5th, 7th, and 9th nerves in relation to visceral slits, or what are supposed to be such. These, as well as the rest of the visceral branches, arise in an altogether different manner to the ganglion and the ramus lateralis, viz., *as an outgrowth from the neural ridge.*

Of these characters, that which has received most attention from morphologists is the distribution to the branchial slits, and the other branches have, till lately, been regarded as secondary in origin, and of much less morphological importance. From this mode of distribution, as well as from the development of the nerve in Elasmobranchs, &c., the vagus has been regarded as essentially a " compound " of a variable number of coalesced " segmental nerves." This is generally supposed to be its *primary* character, and the existing arrangements of the "ramus lateralis " and " ramus visceralis " have been regarded as secondary and special developments. The fact of the existence of a "ramus visceralis" is even regarded by some morphologists [2] as evidence of the previous presence of a number of visceral slits behind those now existing in Selachians. The " segmental nerves " of these supposed slits are believed to have coalesced and remained as the " ramus visceralis." The " ramus lateralis," again, has more recently[3] been supposed to be partly the coalesced

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[1] *Quart. Jour. Mic. Sci.*, 1878; *vide* also " The Morphology of the Vertebrate Olfactory Organ," *Quart. Jour. Mic. Sci.*, vol. xix., 1879.

[2] Gegenbaur, *Elements of Comparative Anatomy*, English translation, p. 520.

[3] Beard, *loc. cit.*

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branch (including the branchial nerves) is to be regarded as equivalent to a number of segmental nerves, what has become of the somatic motor and sensory rami corresponding to them ? Now, this ramus visceralis is, in both Amniota and Ichthyopsida, distributed to a region of the body which presents definite somites, and in which spinal metameric nerves, having somatic sensory and motor branches, are present. May not these be regarded as the somatic rami of the perfect segmental nerves, the visceral branches of which have coalesced into the "ramus visceralis" ? This may be so, but it remains to be shown whether the spinal nerves corresponding to the vagus visceral distribution do or do not give off visceral rami themselves. In the Dog, it is shown by Gaskell that the spinal nerves, from the 1st cervical to the 1st thoracic inclusive, do not contain white visceral rami. It is probable that the vagus contains the visceral rami corresponding to these nerves. If no visceral fibres are present in the anterior spinal nerves in fishes and other types, then we have considerable presumptive evidence that the vagus contains the visceral fibres corresponding to these nerves. Is there any reason why the visceral rami of the anterior spinal nerves in fishes should have coalesced in the way here supposed, whilst the corresponding somatic rami remained separate? It is possible that the visceral rami corresponding to the anterior part of the alimentary canal may have originally been specially modified to form the nerves of the primary chordate respiratory system (gill slits), which we know is of endodermal origin. They may have become specially modified as nerves of respiration, and so have been gradually removed, functionally and anatomically, from the rest of the visceral system. It is further possible that a " concentration " of these respiratory visceral rami took place to bring the whole system under central control. This might have been effected by the development of a "commissural" system, comparable to what takes place in the "sympathetic" in higher types. The connection thus established may have become further specialised, and the original roots of origin from the corresponding spinal nerves gradually lost. In this way a main vagus trunk might have been evolved, having a central origin from the brain, rather than from the spinal nerves of which it really forms the visceral part. Then, as the posterior

gill slits disappeared, and this portion of the alimentary canal ceased to have a respiratory significance, the main commissural trunk may have remained as the "ramus visceralis vagi." This may have taken place without any coalescence of the corresponding somatic rami. I am inclined to adopt these views, and in support of them adduce the following considerations :—

(1) In his account of the development of the vagus in the Dogfish, Balfour described a "ventral commissure" connecting the roots of this nerve together. This he found to be continued onwards as the *ramus visceralis*. He believed that the visceral branch was a commissure, and though this is objected to by Van Wijhe and Beard, yet I do not see sufficient evidence to disprove it. I consider that the existence of this "ventral commissure" and its continuation as the visceral ramus considerably support the views expressed above.

(2) In the course of the development of Petromyzon it is shown by Shipley[1] that the main ganglion of the vagus lies between the 1st and 2nd myomeres. He also shows (page 354) that, at their first appearance, the six posterior gill slits *correspond in extent to the six anterior myomeres*, and subsequently the gill slit region elongates so as to occupy a space corresponding to nine myomeres. Now the first dorsal nerve root is placed between the 3rd and 4th myomeres, so that there are three or four somites corresponding to the respiratory distribution of the vagus, supplied by spinal sensory and motor somatic roots. These facts are very strong evidence in support of the view above stated. The vagus in Petromyzon, if it is in any way "segmental," can only be regarded as composed of so many *visceral* branches, the somatic rami belonging to which have remained separate. The facts also show, that even if the vagus is a compound segmental nerve in any sense, *it by no means follows that the corresponding body-segments have coalesced*, a fact which has an important bearing on the value of the vagus in relation to the question of the segmentation of the head. The importance of caution in estimating the value of the vagus in this matter is also recognised by Parker.[2]

(3) If the views expressed above are justifiable, we should

[1] *Loc. cit.*, p. 361.
[2] Parker and Bettany, *The Morphology of the Skull*, 1877, p. 337, footnote.

expect to find in the anatomy or development of low vertebrate types some relic of the visceral branches of the anterior spinal nerves, which are supposed to have contributed to the formation of the vagus. These we do find in Petromyson. The existence of communications from the spinal roots in this type was described by Born in 1827. This has subsequently been confirmed by Ahlborn,[1] and again by Ransom and Thompson,[2] who, however, do not find any such communications in the allied types *Myxine* and *Bdellostoma*.

(4) Again, if my view of the nature of the " ramus visceralis " be correct, then it morphologically represents in the anterior region of the body the nerve known as " sympathetic " in the posterior parts. It is therefore confirmatory to find in the Cyclostomata that the vagus largely takes the place of sympathetic. Huxley [3] says :—" In the Marsipobranchii, the place of the sympathetic appears to be taken to a great extent by the pneumogastric; and in Myxine the two pneumogastrics unite upon the intestine, and follow it as a single trunk to the anus."

Ransom and Thompson[4] find that " in Petromyzon the vagus in the branchial region includes small commissural (?) fibres derived from the posterior roots, and clumps of ganglion cells derived from the posterior root ganglia (?), that is to say, the typical elements of a " sympathetic." Again, " no segregated parts of spinal ganglia and no such commissural fibres of posterior-root origin occur in the post-branchial region in Petromyzon. The sympathetic is in this animal not only associated closely with the vagus, but it is furthermore peculiar in not extending as a commissural system backwards beyond the branchial region."

(5) Gaskell has shown that the primary nature of the visceral system of nerves is metameric, and that the longitudinal character of the " sympathetic " is secondary. The fact that the visceral metameric rami, corresponding to the upper spinal nerves in the Dog, form a large outflow in the spinal accessory and vagus, and that these spinal nerves do not themselves possess white visceral rami, affords considerable support to my view of the nature of the branchial and visceral distribution of the vagus. It is worthy of note that vagus and sympathetic

[1] *Zeitschr. f. wiss. Zool.*, Bd. xl.   [2] *Loc. cit.*
[3] *Anatomy of the Vertebrated Animals*, p. 78.   [4] *Loc. cit.*, p. 425·

fibres to the heart in some animals run in the same nerve trunk.

(6) The branchial nerves in Selachians give off branches of undoubtedly visceral distribution, viz., the pharyngeal rami.

(7) In the *Amphioxus* we have a type presenting the posterior gill slits, in connection with which the visceral ramus is supposed to have been formed. We should therefore expect an examination of this animal to throw some light on the question before us. This type possesses a central nerve cord in the median dorsal line, from which lateral nerves of two kinds take their origin,—long *dorsal* ones distributed to the body surface, and shorter *ventral* ones which pass to the myomeres. These alternate with each other, and are not quite symmetrically arranged on the two sides of the body. The dorsal branches give off visceral rami, and all the sensory and visceral nerves form a dense plexus which constitutes a commissural system. In this plexus there *does not appear to be any definite longitudinal strand giving off branchial branches* in the way found in the vagus of Elasmobranchs. If then, the hypothesis above propounded as to the origin of the visceral part of the vagus be correct, either the condition in Amphioxus is an extremely primitive one, or a longitudinal visceral vagus, originally present, has been lost. The latter explanation is, I think, untenable, for, though Amphioxus may be in some respects " degenerate," the gill slits are well marked, and there is no reason why a vagus, if once formed, should have disappeared. For a full account of the nervous system in Amphioxus, see a memoir by Rohon.[1]

Having now considered the morphology of the visceral ramus and branchial nerves, and brought forward evidence to show that the primary character of the vagus is rather visceral than " compound segmental," we pass next to a consideration of the " ramus lateralis."

Balfour[2] regarded the lateralis as a dorsal sensory branch of the vagus stem, whose extension backwards is due to the gradual backward elongation of the lateral line. By Beard[3] it is believed

[1] " Untersuchungen über *Amphioxus lanceolatus*," *Denksch. d. k. Akad. d. wiss. Wien*, Bd. xlv.
[2] *Comparative Embryology*, vol. ii. p. 443.   [3] *Loc. cit.*

to be the equivalent of three, four, or more of the dorsal or "supra-branchial" branches of corresponding posterior cranial nerve roots, resulting from the fusion, and peculiar elongated growth of the corresponding "branchial sense-organs." A complete discussion of Beard's results on these organs and their associated nerves and ganglia cannot be here attempted, but from what has been stated on the close developmental association of these structures, there is considerable evidence in support of Beard's view as to the nature of the "lateralis"; but he does not explain clearly why this nerve and its "sense organ" should extend so far backwards, or make clear why a "branchial sense organ" should be found in a region of the body in which gill slits are not asserted to be present even in a remote ancestor; nor does he show any reason why such posterior sense organs should be supplied by nerves having a special mode of formation and closely associated with the vagus, rather than by cutaneous sensory branches from those spinal nerves which are found in the area of vagus distribution.

Baldwin Spencer,[1] who has observed in the Frog the same mode of origin of the ganglia of the cranial nerves and lateralis as that described by Beard in Elasmobranchs, finds that the ganglia of the 3rd, 5th, 7th, 9th, and 10th nerves are formed *at the same level as the lateral line*, and that branches connect some of these together. He says—"The two curious branches which unite respectively the 5th and 7th and 5th and 3rd cranial nerves may be regarded as the persistent parts of the lateral nerve which united the ganglia of the sense organs along the lateral line in the head, and which separating from the skin have come in the course of development to occupy a deeper position, together with the ganglia with which they preserve their primitive connection." It is thus seen that he regards the "lateralis nerve" as part of a commissure between the ganglia of the branchial sense organs.

Ransom and Thompson[2] point out that the Lamprey possesses a lateralis nerve *without a corresponding lateral line*. This fact throws considerable doubt on both Balfour's and Beard's explanation of it. Ransom and Thompson consider the lateralis to be a relic of the commissure system between the dorsal nerve

[1] *Loc. cit.*   [2] *Loc. cit.*

roots of Amphioxus, and in support of this they mention that they believe (though they are not quite certain on this point) that the dorsal spinal roots in Lamprey send branches of communication to the "lateralis" nerve.

The remarkable distribution of the lateralis, which was long ago recognised by Stannius,[1] together with its origin from the epiblast in close relation with the cranial nerve ganglia, and separately from the rest of the nervous system, lead me to believe that it is the representative of some portion of the nervous system of a remote chordate ancestor. Some interesting and highly probable suggestions as to its nature have lately been made by Hubrecht.[2] These suggestions are considerably accentuated in their force if we bear in mind the general resemblances between certain structures found in the Nemertea and what appear to be corresponding organs in Vertebrates. These considerations have led to the formulation of the view that, amongst the Invertebrata, the group of existing animals which in their general organisation approach nearest to the chordate ancestors are the Nemertines. Of this view Hubrecht has been the main advocate, in opposition to the " turn over" theory of Dohrn[3] and his followers. A discussion of these two rival theories is foreign to the subject of this paper, but a general review of the relation of the "lateralis" nerve to the lateral nerve-strands of Nemertines, as well as of the morphologies which follow from an adoption of the views of Hubrecht, will now be attempted.

In the Nemertea the nervous system is in an extremely primitive state, consisting of a general subcutaneous plexus of epiblastic origin. In this plexus there has occurred a specialisation of the fibrils into two lateral strands, and of the cells into a pair of anterior ganglia or brain lobes. The brain lobes are connected by two commissures, of which the dorsal is the larger. Between these commissures there lie the proboscis and its sheath, which Hubrecht identifies with the hypophysis cerebri and notochord respectively.[4] There is also present a more or less

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[1] *Das peripherische Nervensystem d. Fische*, Rostock, 1849.

[2] " The Relation of the Nemertea to the Vertebrata," *Quart. Jour. Mic. Sci.*, vol. xxvii., 1887.

[3] *Der Ursprung d. Wirbellthiere*, &c. Leipzig, 1875; *vide* also Dohrn's " Studien zur Urgeschichte des Wirbelthier.," *Mittheil. a. d. Zool. Stat. zu Neapel*, 1882–87.

[4] " On the ancestral Form of the Chordata," *Q. J. Mic. Sci.*, vol. xxiii., 1883.

definite dorsal median concentration of the plexus, giving rise to a "medullary nerve." This anteriorly joins the dorsal commissure between the brain lobes. In the Schizonemertea and Palæonemertea pairs of metamerically arranged commissural tracts pass circularly round the body *connecting the three longitudinal strands together.* At one time Hubrecht was a supporter of the view first brought forward by Harting,[1] that the Vertebrate central nervous system represents a dorsal coalescence of lateral cords like those of Nemertines, but he has now given up this view, and considers the central nervous system of the Vertebrata to be a specialisation of the dorsal medullary nerve of the Nemertea. He also strongly argues in favour of the identity of the ramus lateralis vagi with the lateral nerve strands of the Nemertea. Following up this hypothesis, he identifies the ganglia of the vagus and other cranial nerves with the brain lobes of the Nemertea; and the "visceral ramus" of the vagus, with a special branch from the posterior part of the brain lobes distributed to the anterior part of the alimentary canal in Nemertines, and to which he has given the name of "vagus nerve." I agree with him in this identification of the "ramus visceralis," but I go further,—I believe it has arisen in the Nemertea in the same way as in Vertebrata, by a concentration in relation to respiration of the visceral fibres distributed from the metameric strands to the anterior part of the alimentary canal. In support of this I mention two facts—(a) there appear in the early development of the Nemertea a pair of lateral diverticula from the anterior part of the alimentary canal, comparable to the first pair of gill slits in a Vertebrate embryo,—these are shown by Hubrecht[2] to have a respiratory function; (b) there is an intimate connection between the visceral branches of the metameric nerve strands and the "vagus" in Nemertea, comparable to the similar connections in Petromyzon.

I agree with Hubrecht in his views on the morphology of the cranial ganglia and lateralis vagi; and on the following grounds:—

(1) The "lateralis" arises as an independent product of the

[1] *Leerboek van de Grondbeginselen der Dierkunde,* 1874.

[2] "Zur Anatom. und Phys. des Nervensystems der Nemertinen," *Verhand. van de Koninkl. Akad. van Wetenschappen,* Amsterdam, 1880.

epiblast along the region which will become, the lateral line. Its position is strictly lateral.

(2) The ganglia of the 3d, 5th, 7th, 9th, and 10th cranial nerves appear as independent products of the epiblast at the sides of the head *in a line with the lateralis nerve*. This is shown by Froriep[1] in mammals, Baldwin Spencer in Frog, Beard and Van Wijhe in Elasmobranchs, and Shipley in Petromyzon.

(3) The Lamprey has a lateralis nerve *without a corresponding "lateral line"* (Ransom and Thompson).

(4) The "lateralis," in Petromyzon, receives branches from the dorsal roots of the spinal segmental nerves comparable to the circular metameric strands in Nemertea.

(5) The presence of an epiblastic nerve plexus in an early stage in the development of the Frog (Spencer) and in other Amphibia (Goette).[2] This is comparable to the general nerve plexus in the adult Amphioxus (Rohon), and all three instances are highly suggestive of the nerve plexus of Nemertea.

(6) The identity in position of the brain and spinal cord in Vertebrata and the dorsal median nerve of the Nemertea; and the formation of the former as a median structure, without any indication of a double character, except in one vertebrate type—Newt.[3]

(7) The formation of the "ramus lateralis," *independently of the rest of the vagus.*

The conclusions thus arrived at lead us to several other homologies:—

If Gegenbaur's idea that lateral cords, like those of Nemertea, may have coalesced to form the ventral ganglionic chain of Annelids and Arthropods be accepted, then the "rami laterales" of the Fish's vagus are probably homologous with the main nervous system of these groups.

It is highly probable that the visceral system of nerves in connection with the anterior ganglia of the Annelida and

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[1] "Ueber Anlagen von Sinnesorganen am Facialis, &c," *Arch. f. An. und Phys.*, 1885.

[2] *Entwicklungsgeschichte der Unke.*

[3] Scott and Osborn—"On some Points in the Early Development of the Common Newt," *Quart. Jour. Mic. Sci.*, vol. xix., 1879.

Arthropoda, is equivalent to the visceral part of the vagus; and it is possible that the " azygos nerve " of the " stomato-gastric " system of such a type as Astacus is equivalent to the medullary nerve of Nemertea, and therefore to the central nervous system of Vertebrata.

Balfour[1] concluded, from a study of larval forms, that bilateral symmetry arose by an elongation of a radiate ancestor, and that the nerve ring of Coelenterates may have formed the lateral cords and anterior ganglia. If this is accepted, then it is probable that the " lateral " branches of the vagus, equivalent to the lateral strands of Nemertea, are morphologically the same as the nerve ring of the Coelenterata. In this case, the " rami laterales " and the ganglia of the cranial nerves would appear to be the relic of the most primitive of the nerve trunks found in the nervous system of the lowest types. On the other hand, the two conditions may have been independently evolved from the general subcutaneous epiblastic plexus, which forms the most elementary nervous system known.[2]

Summary.—Though not conclusively proved, there is evidence to show :—

1. That the vagus is a " compound nerve," but not in the sense generally supposed; it is rather a compound of the visceral rami of the anterior spinal nerves, and of the remnants of the brain-ganglia and lateral cords of the nervous system of Invertebrata, than of several metameric nerves.

2. That the visceral part of the vagus of fishes includes the branchial nerves, and has arisen from a coalescence of the visceral rami of the anterior spinal nerve segments, the corresponding motor and sensory somatic branches of which have remained separate.

3. That the ganglia of the cranial nerves (5th, 7th, 9th, and 10th) are the representatives of the brain lobes of Nemertea, and probably of the cerebral ganglia of Annelida and Arthropoda.

4. That the " ramus lateralis " is of extreme ancestral origin, and is equivalent to the lateral strands in the nerve plexus of

[1] *Comparative Embryology*, vol. ii. p. 317.
[2] *Vide* Balfour, *Comparative Embryology*, vol. ii. p. 330, " The Origin of the Nervous System."

Nemertea, to the main nervous system of Annelida and Arthropoda, and possibly also to the nerve ring of Cœlenterata.

5. That a study of the vagus nerve throws light on the question of the chordate ancestor, and does not tend to support the views of Dohrn and his school.

6. That the value of the vagus in deciding the question of the segmentation of the vertebrate head has been much overrated.

In conclusion, it seems to me that the views here expressed could be to a great extent tested by a study, on the plan initiated by Gaskell in the Dog, &c., of the histological composition of the various parts of the vagus of Elasmobranchs, in relation to the spinal visceral rami. The points which require elucidation are—(a) whether the "ramus visceralis" is chiefly composed of fibres having the same nature as the visceral fibres of the spinal nerves; (b) the characters of the fibres composing the branchial nerves, and whether or not they agree with those of the visceral branch; (c) a comparison of the minute characters of the fibres in the ramus lateralis with those of the rest of the nervous system; (d) whether the spinal metameric nerves of the segments corresponding to vagus visceral distribution do or do not contain visceral fibres.

With these points I hope to deal in a subsequent paper.

THE MUSCULUS STERNALIS. By D. J. CUNNINGHAM, M.D. (Edin. & Dubl.), *Professor of Anatomy and Chirurgery in the University of Dublin.* (PLATE XVI.)

OF the many views which have at different times been entertained regarding the nature of the musculus sternalis, that which refers it to the panniculus carnosus has received wider acceptance than any other. This has been largely due to the opinion expressed by Sir Wm. Turner,[1] who, after having studied a greater number of cases (21) than any other observer, stated that it may perhaps be regarded as a rudiment in man of the panniculus, though he recognised and stated that it was on a deeper plane than the platysma. It now appears, however, that this theory must be displaced by one more recent, viz., that the sternalis is merely a portion of the pectoralis major. It was Bardeleben [2] who first enunciated this view, but he did so in a very restricted form. He considered that only a certain proportion of the muscles which receive the name of "sternalis" (21 per cent.) could come under this category. A few years later Dr Abraham,[3] from a study of the muscle in anencephalous foetuses, extended this view, and applied it, without limitations of any kind, to every form of musculus sternalis. More recently the writer of this paper,[4] and also Professor Shepherd [5] of Montreal, have given expression to a similar opinion. The strongest evidence in favour of regarding the musculus sternalis as being a piece of the pectoralis major is the fact that it receives its nerve of supply from one or other, or from both of the anterior thoracic nerves.

For four years I have kept a record of the different cases of this anomaly which have appeared in the dissecting room of

[1] "On the Musculus Sternalis," *Jour. Anat. and Phys.*, vol. i., 1867.

[2] "Der Musculus Sternalis," *Zeitsch. für Anat. und Entwickelungsgesch.*, Bd. i., 1876.

[3] "Notes on the Occurrence of the Musculus Sternalis in Human Anencephalous Foetuses," *Trans. Acad. Med. in Ireland*, vol. i., 1883.

[4] "The Musculus Sternalis," *Jour. Anat. and Phys.*, vol. xviii., 1884.

[5] "The Musculus Sternalis and its Occurrence in Human Anencephalous Foetuses, *Jour. Anat. and Phys.*, vol. xix., 1885.

Trinity College, Dublin, and I have carefully studied the nervous relationships which were presented by each. I need not refer to the attachments of the musculus sternalis. These have been sufficiently dealt with by the many authors who have written on this subject from the time of Cabrolius (1604) down to the present day. It is only necessary for me to mention in passing that I have seen no example of the sternalis which could not be referred to one or other of these descriptions. But before entering upon the question of its nerve-relationships, it is well that I should refer to the observations which have already been made upon this aspect of the subject.

So far as I am aware, it was Hallett[1] who first made any statement upon the nerve-supply of the musculus sternalis. Forty years ago, in the description of a large example of this muscle, he remarks that it was supplied by the third, fourth, and fifth intercostal nerves. No attention appears to have been paid to this observation, and no use of it has been made by the numerous anatomists who have, since that date, endeavoured to ascertain the homologies of the musculus sternalis.

In 1876 Malbranc,[2] by means of electrical stimuli, was enabled to verify the existence of the sternalis muscle in two living subjects. The first case was that of a young man in whom faradisation of the intercostal nerves excited the contraction of the muscle. The second case also occurred in a male, but in this instance the contraction of the muscle could only be brought about by faradisation in the course of the anterior thoracic nerves.

Bardeleben[3] is the next authority who refers to the nerve-supply of the musculus sternalis. In 1876 he published a very elaborate paper upon the sternalis, in which he gives in tabular form an outline account of the various descriptions which had been recorded of the muscle up to that date. In all he collects 117 cases, and to these he adds three of his own, one of which he figures. The views he expresses are somewhat peculiar, inasmuch as he considers that the sternalis presents a different significance in different cases: 21 per cent., he believes, belong to the pectoralis major; 55 per cent. to the sternomastoid; and 6 per cent. to the platysma. In this paper he makes no allusion to the nerve of supply, but a year later he records[4] two additional cases. In the first of these, which occurred in a three-months-old female child, he does not mention the nerve-supply; in the second

[1] "Muscular System of the Human Body," *Edin. Med. Jour.*, vol. lxix. p. 21, 1848.

[2] "In Sachen des Sternal Muskels," *Zeitsch. für Anat. u. Entw.*, Bd. ii. p. 310.

[3] *Zeitsch. für Anat. und Entwick.*, Bd. i. p. 424.

[4] "Einige seltnere Muskelvarietäten," *Sitz. berich. der Jenaischen gesellschaft*, März 1877.

the muscle was present on both sides of an elderly female, and he states that "the nerves came on both sides from the second and third intercostal nerves." Further, referring to his former paper, he remarks that "later investigation has rendered it very likely" that the case which he at that time figured was supplied by the anterior thoracic nerves.

In 1883 the writer of this paper described a case[1] of sternalis in which he had traced the nerve supply from the internal anterior thoracic nerve. Since that time numerous observations have been made upon this point. Professor Shepherd,[2] in seven out of nine muscles found in six anencephalous fœtuses, traced the nerve-supply from the anterior thoracic nerves. In one of these, however, the muscle received an additional minute twig from one of the intercostals. In the remaining two muscles, which occurred in the same fœtus, he was unable to satisfactorily make out the nerve-supply, but he was inclined to believe that it came from the anterior thoracic nerves. In the Anatomical Department of the Edinburgh University the nerve supply of the sternalis has been traced in five adult subjects to no less than seven muscles. In one instance, Dr David Wallace[3] found it proceeding from the external anterior thoracic nerve; in the others it was traced by Dr J. C. Lamont. In four of these it came from the external anterior thoracic, in one from the internal anterior thoracic, and in one from both.[4] Neither of these observers could detect any branches to the sternalis from the intercostals, but Dr Lamont states that in one case an intercostal nerve communicated by a fine twig with the nerve of supply from the anterior thoracic before it entered the muscle.

Within the last few months Professor Dwight[5] of Harvard College has published some observations on the sternalis and its nerve of supply. He describes seven cases. In two of these he traced the nerves from the intercostals. Referring to a third he says—"Nerve-supply from a slender nerve which entered the deep surface of the muscle opposite the 3rd intercostal space, and which was traced through the pectoralis major nearly to the border of the axilla. . . . The left nerve was smaller than the right one. They probably came from one of the anterior thoracic nerves."

During the last four years 358 subjects have been dissected in the Practical Anatomy Room of Trinity College. In sixteen of these the musculus sternalis was observed. This gives a percentage

[1] *Jour. Anat. and Phys.*, vol. xviii., 1884.

[2] *Jour. Anat. and Phys.*, vol. xix., 1885.

[3] "Note on the Nerve Supply of the Musculus Sternalis," *Jour. Anat. and Phys.*, vol. xxi., 1886.

[4] "Note on the Nervous Supply of the Musculus Sternalis," *Jour. Anat. and Phys.*, vol. xxi., 1887.

[5] "Notes on Muscular Abnormalities," *Jour. Anat. and Phys.*, vol. xxii., Oct. 1887.

of 4·4. Sir Wm. Turner,[1] who examined 650 subjects, and Professor Macalister,[2] who examined 350, both found it present in about 3 per cent. of these; but Professor Wenzel Gruber,[3] who specially examined 100 subjects with the view of determining the frequency of this anomaly, discovered it in five.[4] In addition I have dissected six anencephalous human fœtuses, but with so little success that I only found the musculus sternalis present in one specimen. My experience, therefore, in this respect falls far short of that of Dr Abraham, who found it present in six out of eleven anencephalous monsters, and of Professor Shepherd, who found it in each of the six specimens he dissected.[5]

A cyclopean monster having recently come into my possession, I took the opportunity of examining the pectoral region, but there was no trace of the sternalis.

The table on page 395 gives the nerve supply to the musculus sternalis in those cases in which I have been able to determine it. Including the anencephalous fœtus in which the anomaly occurred, there were five cases in which the muscle was present on both sides. Twenty-two muscles were therefore observed, but in five the nerve was not secured. In three cases the muscle had been cleaned and isolated before attention was attracted to it, and in the other two instances it was so minute that I altogether failed to discover the nerve.

In the seventeen cases in which the nerve of supply was traced it was found to come from one or other or from both of the anterior thoracic nerves. The course pursued by this nerve has already been so fully described by Professor Shepherd, Mr Wallace, Dr Lamont, and by myself in my former paper, that I need not enter into details on this point. The large number of cases, however, which I have had an opportunity of studying

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[1] *Jour. Anat. and Phys.*, vol. i., 1867.

[2] " Additional Observations on Muscular Anomalies in Human Anatomy (third series), with a Catalogue of the Principal Muscular Variations hitherto published," *Trans. Roy. Irish Acad.*, vol. xxv.

[3] *Mem. de l'Acad. Imp. de St Petersbourg*, tome iii., 1860.

[4] During the Christmas recess of the present session twenty subjects have been received into the anatomy department of Trinity College, Dublin. Having examined each of these specially, I found the musculus sternalis in two.

[5] Professor Dwight states, in his article already quoted, that he has examined several anencephalous fœtuses, and only found it once.

since I first wrote on this subject have enabled me to determine some points which appear to me to be of importance.

The origin of the nerve, whether from the internal or from the external anterior thoracic, or from both, is a matter of little morphological significance. It is unnecessary, therefore, for me to pursue this question beyond the mere statement that in the majority of cases it appears to derive fibres from both of these nerves (fig. 3).

The point at which the nerve emerges through the great

Nerve-Supply of Seventeen Cases of Musculus Sternalis.

No.	Sex.	Single or Double.	Nerve of Supply.
1.	Female.	Double.	Right. From internal anterior thoracic. Left. The muscle was isolated before attention was attracted to it.
2.	Do.	Single.	From internal anterior thoracic and loop between it and external anterior thoracic.
3.	Do.	Do.	Muscle so feeble that the nerve was not secured.
4.	Do.	Do.	From internal anterior thoracic.
5.	Do.	Do.	The muscle was isolated before attention was drawn to it.
6.	Do.	Do.	From external anterior thoracic.
7.	Do.	Do.	From internal anterior thoracic and loop between it and external anterior thoracic.
8.	Male.	Do.	From internal anterior thoracic.
9.	Do.	Do.	From internal anterior thoracic.
10.	Do.	Double.	Right. Muscle isolated before attention was drawn to it. Left. From external anterior thoracic, slight root also from internal anterior thoracic.
11.	Do.	Single.	Muscle so minute that no nerve could be found.
12.	Female.	Double.	Right. From internal anterior thoracic and loop between it and external anterior thoracic. Left. From external anterior thoracic and loop between it and the internal anterior thoracic.
13.	Male.	Do.	Right. From external anterior thoracic and loop between it and internal anterior thoracic. Left. Do. do.
14.	Do.	Single.	From thoracic nerves; traced to thoracic plexus in substance of pectoralis major.
15.	Do.	Do.	From internal anterior thoracic and loop between it and external anterior thoracic.
16.	Do.	Do.	From external anterior thoracic.
17.	Anencephalous foetus, female.	Double.	Right. From internal anterior thoracic. Left. From internal anterior thoracic.

Summary.—Twenty-two muscles ; nerve traced to seventeen of these from one or other or both of the anterior thoracic nerves.

pectoral muscle varies in different cases, and seems to depend on the degree of development and degree of obliquity of the sternalis. As a rule, it makes its exit about the level of the third rib, and it enters the fleshy belly a little lower down. But sometimes it appears at a higher level and often at a lower level. In one instance it did not emerge from the great pectoral until it had gained the under surface of the sternalis, and in this case it was only discovered by raising the muscle from the surface of the pectoral.

The length of the nerve is very remarkable. It measures as a rule 8½ to 9½ inches. Further, the manner in which it is connected with the pectoral muscles and the sternalis is most instructive: as it traverses the pectoralis major it gives many twigs to it (figs. 1 and 5), and in almost every case it likewise supplies numerous fine filaments to the pectoral muscle as it travels inwards upon its surface (figs. 2, 4, and 5). Finally, it sinks into the deep surface of the sternalis. In many instances (especially where the muscle was small and the nerve slender) it was found to communicate freely with the thoracic nerve plexus in the substance of the greater pectoral, and in one case I was quite unable to trace it through this, and therefore failed to satisfy myself as to whether it sprang from the external or the internal thoracic nerve. In one instance two nerves pierced the pectoralis major, gave branches to its surface, and entered the musculus sternalis at different levels (fig. 2). Both of these took origin under cover of the greater pectoral from a common stem. Whilst this must be regarded as an unusual occurrence, it is not uncommon to find two nerves piercing the greater pectoral at different levels, but of these only one reaches the sternalis (figs. 2 and 5). The other, it may be the higher or it may be the lower, as it runs inwards gradually exhausts itself in branches to the surface of the pectoralis major, and finally disappears before it gains the margin of the sternalis. I have not seen this nerve in subjects in which the sternalis is absent, but in one case of single sternalis a nerve was observed upon the opposite side having a somewhat similar arrangement.

The points which I would wish to lay stress upon in connection with the nerve of supply to the sternalis are :— (a) the great length of the nerve; (b) that when the sternalis is present one or two fine nerve twigs run inwards upon the pectoralis major and

give filaments to its surface; as a rule, only one of these reaches the sternalis; (c) the frequent connection of the nerve to the sternalis with the thoracic nerve plexus in the substance of the great pectoral. These are points which I believe will assist us in arriving at a correct estimate of the homologies of the sternalis muscle.

But we have already noted that Hallett, Bardeleben, and Dwight have stated that they have traced nerves of supply into the musculus sternalis from some of the intercostal nerves. I have sought most anxiously for evidence of this in the cases I have had at my disposal, but have never been able to detect such a supply. And latterly, being disappointed at my repeated failures in this respect, I have handed over the dissections, when the muscle presented itself, to my assistant, Dr H. St John Brooks, in whose skill and care as a dissector I have great confidence. In all he has dissected six cases, and whilst he obtained in each the thoracic nerve-supply, he completely failed to discover any branches from the intercostals ending in the sternalis. I do not on this account doubt the accuracy of the observations of those authors whose experience in this respect is different from my own, but I am inclined to think that it is just possible that with the intercostal supply there may have been also a thoracic supply which has been over-looked. Of such a nature is one of the cases recorded by Dr

Musculus Sternalis.

Authority.	Supplied by Anterior Thoracic Nerves.	Authority.	Supplied by Intercostal Nerves.
Shepherd,	7 Muscles.	Hallett,	1 Muscle.
Wallace,	1 ,,	Bardeleben,	2 ,,
Lamont,	6 ,,	Dwight,	2 ,,
Dwight,	2 ,,		
Cunningham,	17 ,,		
Total,	33 ,,	Total,	5 ,,

Shepherd; and one of Dr Lamont's cases also bears a resemblance to this form of supply. But even granting that in some rare cases the intercostal nerves do assume the entire responsibility of giving nerves of supply to the sternalis, this would in

no way (as I shall afterwards point out) invalidate the doctrine that the sternalis is a part of the pectoralis major. In the preceding table I give the number of cases recorded of both kinds of supply.

Bardeleben is of opinion that those varieties of the sternalis which receive their nerves from the intercostals are derivatives of the sternomastoid, whilst those which obtain them from the interior thoracics belong to the pectoral group. Such a view is altogether untenable, because in the majority of the cases which I record as receiving the nerve of supply from the thoracic nerves, the muscles were directly connected by tendinous continuity with the sternomastoid (figs. 1, 2, and 4).

The close examination to which I subjected the intercostal nerves in their relation to the different cases of the musculus sternalis was not without interesting results. As a rule, the first anterior cutaneous nerve pierced the upper tendinous portion of the sternalis (figs. 1 and 5); but in some cases it appeared through the pectoralis major upon the outer side of the anomalous muscle, and at once proceeded outwards (fig. 2). The other anterior cutaneous nerves varied in their relations according to the degree of obliquity of the sternalis and the points at which they emerged from the pectoralis major. When the muscle presented the usual degree of obliquity, and the terminal branches of the intercostals pierced the pectoralis major close to the sternum, they appeared along the inner margin of the muscle, and then turned outwards upon its surface. In those cases, however, in which the entire sternalis or a portion of it presented a more or less vertical direction, and was placed close to the margin of the sternum, the terminal twigs of the intercostals came to the surface of the great pectoral, either under cover of the muscle, or on its outer side. When this was the case, the course which the nerves took was most instructive. They did not at once turn outwards, but were continued inwards beneath the sternalis, until its inner border was reached. Hooking round this they then proceeded outwards to their distribution. In these cases, therefore, they adopted a distinctly recurrent course (fig. 4). And the same might be seen when one or more of the lower intercostal nerves came to the surface at a greater distance from the sternum than usual.

Having now stated the results of my investigations into the nerve connections of the sternalis, we may in the next place consider the light which they throw upon the homological aspect of the question. The fact of the muscle being supplied by the anterior thoracic nerves affords very strong evidence in favour of its being regarded as a piece of the pectoralis major. There are other conditions present, however, which still further emphasise this view. In all the cases which came under my notice the sternalis lay altogether upon the superficial aspect of the pectoralis major, and in none was there any marked deficiency in the greater pectoral muscle. The appearance of the parts produced the impression that the sternalis had been formed by a deviation or dislocation of the pectoral fibres from above downwards and inwards. The nerve of supply is dragged inwards by the deviating fibres, and this accounts for its great length, and also for its frequent connection with the thoracic nerve plexus in the substance of the pectoral muscle. By the separation of the superficial fibres of the pectoralis major, the exposure of the nerve, which is sometimes seen running inwards upon its surface, and giving branches to it, is explained. But additional proof of the inward dislocation of some of the sternal fibres of the great pectoral to form the sternalis is found in the occasional recurrent course of the intercostal nerves. This suggests in the most striking manner the probability that the nerves have been pushed inwards by the deviating fibres. The condition of these nerves may be compared with that of the second lumbrical nerve of the foot, which has been dragged forwards, and obliged to adopt a recurrent course, by the advancing transversalis pedis.[1]

Those cases in which the first intercostal nerve pierces the sternalis may be explained by supposing the centre of the rotation of the fibres to have been placed in the neighbourhood of this nerve; when the first intercostal nerve appears upon the outer side of the sternalis, the rotation must have taken place below it. The fact that the sternalis may derive its nerve-supply from one or other of the anterior thoracic nerves shows that the same set of fibres is not always implicated in this rotation.

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[1] "Variations in the Nerve Supply of the Lumbrical Muscles," H. S. J. Brooks, M.D., *Jour. Anat. and Phys.*, vol. xxi.

But whilst the greater number of the cases which I have had an opportunity of studying may be accounted for in this manner, there cannot be a doubt that the dislocation of pectoral fibres may take place in a variety of ways. Where a marked deficiency exists in the pectoralis major, it is reasonable to suppose that the gap is caused by the abstraction of this portion of the muscle to form the sternalis, and there are many cases figured which would lead one to suspect that the rotation of fibres has taken place in an upward and inward direction. In this manner only can we account for those cases in which the lower end of the sternalis lies under cover of a portion of the great pectoral. This variety of the anomaly is particularly common in anencephalous fœtuses. Whilst in the adult we, as a rule, find the deviating fibres derived from the superficial aspect of the pectoral muscle, in the anencephalous fœtus there appears to be a tendency to rotation in both the superficial and deep fibres of the pectoralis major, the intermediate fibres alone retaining their usual course. This may be seen in several of the admirable figures which illustrate the papers by Dr Abraham and Dr Shepherd.

The different steps by which the sternalis is formed by deviating pectoral fibres could only be satisfactorily established by the study of embryos in which the muscle was in process of development. The chance of such embryos falling into the hands of an observer interested in the subject is a very remote one, and in the meantime we must base our conclusions upon the surroundings of the muscle as it appears in its fully developed condition.

At this stage it will be convenient to discuss the theory regarding the nature of the musculus sternalis which has been advanced by M. Testut. Although at first sight this appears very different from that which we are at present advocating, we shall find that, by correcting a defect in his argument, it is brought entirely into accord with the views we have stated. M. Testut[2] expresses his belief that the musculus sternalis in its upper part belongs to the sternomastoid, whilst in its lower

[1] See fig. 1 by Dr Abraham, and figs. 2, 4, and 6 by Dr Shepherd. In fig. 5, by the latter observer, the intermediate fibres also appear to be involved.

[2] " Le Muscle Présternal et sa Signification Anatomique," *Jour. de l'Anat. et de la Phys.*, 1884 ; also " Les Anomalies Musculaires chez l'Homme," 1884.

part it belongs to the external oblique. He points out that these two muscles, with which he associates it, occupy the same morphological plane, and that they exhibit an identity of situation, direction, and attachments. Further, in the Serpent they are continuous, because, as Professor Humphry has shown so conclusively, the anterior fasciculi of the external oblique in the Serpent represent the sternomastoid in the Batrachian, bird, and mammal. But M. Testut, having laid down these propositions, with all of which we agree most fully, goes on to state that in the thrusting out of the anterior limb the connection between the external oblique and the sternomastoid is lost, a hiatus or gap is formed between them, and the musculus sternalis, when it occurs, is the representative of that part of the primitive continuous muscular sheet which originally connected the hinder external oblique portion with the anterior sternomastoid portion. It is here that M. Testut's argument is defective. The thoracic or intermediate portion of this muscular sheet is not suppressed; it does not disappear with the protrusion of the limb, but the direction of its fibres is altered, and it forms the pectoralis major. The external oblique, the pectoralis major, and the sternomastoid all occupy the same morphological plane, and together represent the external oblique of the Serpent. I do not advance this view upon my own reponsibility alone. It is the view which is so ably advocated by Professor Humphry in his article upon "The Disposition of Muscles in Vertebrate Animals." Speaking of the layer in question, he says—" Anteriorly it is continued, or its superficial fibres are continued, with a variable amount of interruption, into a superficial brachio-cephalic sheet which extends to the face and head, which is distorted by encountering the forelimb and its girdle, and the fibres of which converge upon the limb as though, like the skin, they had been pushed before it as it grew from the girdle. Hence, opposite the limb, the fibres are directed transversely, from the ventral and dorsal mesial lines upon the limb, whereas before and behind the limb they have a more oblique or antero-posterior direction." And then he goes on to remark—" As it advances towards the fore limb, the inferior or ventral part of the superficial brachio-cephalic sheet resolves itself into the pectoralis major."

It is not necessary, therefore, to imagine the reappearance of suppressed muscular fasciculi for the purpose of bridging over the supposed hiatus between the external oblique and the sternomastoid.   Muscle fibres belonging to the same muscular sheet exist ready to hand in the pectoralis major, and a deviation in the direction of some of these will re-establish the primitive continuity, and at the same time form the musculus sternalis.

So much, then, for the source from which the fibres of the musculus sternalis are derived.   Can any explanation be given of its occurrence ?   In the light of the foregoing observations the answer which most naturally offers itself to this question is, that the deviation of the pectoral fibres shows a tendency on their part to re-establish their original direction and connections. Such a view may be considered to receive some support from the fact that occasionally the musculus sternalis obtains its nerve-supply from the intercostals.   This may be regarded as indicating a tendency on the part of these fibres to revert to the supply which exists in the limbless condition, or, in other words, to the supply which is present in the Serpent.

The defective point in this theory is, that the sternalis has only been observed in man.   It has never been observed in any of the lower animals, and it would be curious, therefore, if in man alone this tendency to reversion towards the serpent condition was exhibited.   It is true that the dissection of the human body is much more frequent and much more carefully conducted than that of the lower animals; still, if it does occur in the latter, it is reasonable to expect that it would have been met with, and the lower the animal the greater should be the tendency to the reversion.[1]   Dr M'Fadyean, the able professor of anatomy in the Dick's Veterinary College, informs me that he has never seen the sternalis in the horse, and that he is convinced that, had it occurred in any of the subjects dissected during his time, he would have observed it.   He has superintended the dissection of 150 horses.   In the stores of the ana-

[1] In pushing this argument we must not lose sight of the fact that there is less tendency to variation in the muscular system of the lower animals than in man. This is probably due to the fact that the erect attitude which has been assumed by man has caused a more sudden and abrupt change in his muscular system than has occurred in the different lower animals.

tomical department of Trinity College there are at present 24 apes of different kinds, four being members of the anthropoid group. Dr Brooks has kindly dissected the pectoral region of these for me, and in none was there the slightest trace of a sternalis.

Another point which is somewhat unfavourable to the reversion theory is, that the fibres of the sternalis run in a different direction from those of the external oblique and the sterno-mastoid. As a rule, they are directed from above downwards and outwards.

But, on the other hand, if we can show that the musculus sternalis, when present, can perform any function useful to the organism, there would be some ground for regarding the anomaly as a new muscle gradually appearing in man. Not a new muscle in point of derivation, but new in so far as a portion of an existing muscle is specially modified and set aside to perform a new function. In Hallett's paper, published in 1848, I find the following statement:—" When fully developed it (*i.e.*, musculus sternalis) can act as an elevator of the ribs, and, as I shall show when I come to speak of the use of the supernumerary muscles in general, may be of great service, under certain circumstances, by acting as a muscle of inspiration." In support of this view of its action he quotes the case of an old man in whom all the ordinary muscles of inspiration were completely degenerated and replaced by fat, and in whom a musculus sternalis, largely developed, was healthy, and sufficient of itself to maintain costal respiration.[1]

The assumption by man of the erect attitude has certainly imposed a greater burden upon the costal inspiratory muscles, and it is just possible that the sternalis is being slowly called into existence for the purpose of increasing the inspiratory power. Taking origin, as it usually does, from the manubrium sterni or the tendon of the sternomastoid, it extends downwards and outwards to its insertion into some of the lower rib cartilages and the aponeurosis of the external oblique. Placed upon

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[1] Malbranc, by exciting contraction of the muscle in the living subject, came to the conclusion that, in one of the two cases in which he observed it, the sternalis did not come into play in ordinary deep inspiration, but acted as a muscle of extraordinary inspiration.

the superficial aspect of the chest wall, its fibres cross those of the triangularis sterni, which lies upon the deep aspect of the chest wall, in the same manner that the fibres of the two layers of the intercostal muscles cross each other. In its action, then, when fully developed, it must be antagonistic to the triangularis sterni.

In connection with this view of the sternalis, it is important to decide its relative frequency in the two sexes. If it be a new inspiratory muscle, there would be some reason to expect that it would occur more frequently in the female, seeing that costal respiration is more pronounced in women than in men. I have gone carefully into this matter, and have collected all the cases available in which the sex is mentioned. The following table shows the result:—

Relative Frequency of the Musculus Sternalis in the two Sexes.

Authority.	Male.	Authority.	Female.
Bardeleben's Table, .	27	Bardeleben's Table, .	25
Malbranc, ...	2	Bardeleben, . . .	2
Shepherd, ...	3	Wallace, ...	1
Ledouble,[1]	2	Lamont,[5]	4
M. Issaurat fils,[2] . .	1	Ledouble, ...	1
Joessel,[3]	1	Dwight, ...	3
Dwight, ...	3	Curnow, ...	3
Curnow,[4]	2	Cunningham, . . .	8
Cunningham, . . .	8		
Total, . . .	49	Total, . . .	47

It is somewhat curious to find that a nearly equal number of each sex in which the sternalis has been noted is recorded. But there is a fallacy in these statistics in so far as the proportion

[1] "Sur le Muscle Sternal chez l'Homme," *Bull. Soc. d'Anthrop.*, 1879, 3e fasc., p. 408.

[2] "Un cas d'Anomalie Reversive," *Bull. Soc. d'Anthrop.*, 1879, 2e fasc., p. 121.

[3] "Ein besonderen Fall von Musculus Sternalis," *Archiv für Anat.*, 1878, p. 429.

[4] Communicated to the writer by letter.

[5] Dr Lamont does not mention in his article quoted above the sex of the subjects in which he found the sternalis, but in a letter I have had from him he informs me that four were females, and that he does not recollect the sex of the remaining case.

of males and females dissected is very different in different ana-tomical departments. In Edinburgh I know that female subjects are always in excess of males; and this may account for the fact that Sir William Turner observed the sternalis in 11 females and in only 7 males. The same may be said for Dublin. During the last four years I find that the female subjects dissected in Trinity College are in excess of the males in the proportion of 13 to 10. On the other hand, Bardeleben appears to consider that on the Continent male subjects are more fre-quently dissected than females. Taking all these facts into account, therefore, it is difficult to come to a decision on this point. Most probably, as Bardeleben has already stated, the proportion of the two sexes in which the sternalis appears is about equal.

The relative frequency of the double sternalis in the two sexes is also a matter of interest. Unfortunately the authors who have recorded cases of this kind have seldom noted the sex. Although Bardeleben tabulates 43 cases in which the muscle was present on both sides, in only 10 of these is the sex mentioned.

Relative Frequency of Double Sternalis in the two Sexes.

Authority.	Male.	Authority.	Female.
Bardeleben's Table, .	6	Bardeleben's Table, .	4
Malbranc, . . .	1	Ledouble, . .	1
Ledouble, . .	1	Dwight, . . .	1
Joessel, . . .	1	Curnow, . . .	2
Dwight, . . .	1	Cunningham, . .	2
Curnow, . . .	1		
Cunningham, . .	2		
Total, . .	13	Total, . .	10

According to these figures the excess is slightly in favour of the male, but the numbers are too meagre for us to draw any useful inference from them.

When I first put forward the inspiratory view of the mus-culus sternalis, I was under the impression that the anomaly

occurred more frequently in the female than in the male.[1] In this, however, I was evidently in the wrong; and whilst I still believe that the explanation is a reasonable one, I am by no means prepared to assert that it is in all respects satisfactory. Perhaps the most rational view to take of the question is to consider the anomaly as a reversion, which, when it occurs, performs a useful function, and may therefore in time become firmly established as a normal condition.

The frequent occurrence of the sternalis in anencephalous monsters is indeed hard to understand; and if it can be adduced in support of either view, it certainly favours the reversion theory, as Professor Shepherd has pointed out.

An outline of this paper was read before the biological section of the British Association in Montreal in 1884, under the title of " The Value of Nerve Supply in the Determination of Muscular Anomalies." At the same time I also recorded two cases in which I had traced the nerve supply of the axillary muscular arches from the internal anterior thoracic nerve. I did not publish my observations at the time, in order that I might still further extend my experience of the musculus sternalis.

EXPLANATION OF PLATE XVI.

Fig. 1. Sternalis muscle in a female subject. Drawing taken from a preparation preserved in Anatomy Department of Trinity College, Dublin. *a.*, sternalis with intercostal nerves hooking round its inner margin; *p.*, pectoralis major; *c.*, internal anterior thoracic nerve; *d.*, pectoralis minor; *e.*, cords of brachial plexus; *f.*, external anterior thoracic nerve; *g.*, pectoralis major; *i.*, sternal head of sternomastoid.

Fig. 2. Double sternalis in male subject. Relation of intercostal nerves displayed. On each side two nerves pierce the great pectoral muscle and run inwards. On the left side both reach the sternalis; on the right side the upper of the two exhausts itself in branches to the great pectoral before it reaches the sternalis.

Fig. 3. Dissection under water of the anterior thoracic nerves and the connecting arch. *i.a.t.*, internal anterior thoracic nerve; *e.a.t.*, external anterior thoracic nerve; *P. maj.*, branches to pectoralis major; *P. min.*, branches to pectoralis minor; *s.*, branch to sternalis.

[1] At that time I had observed no case of the sternalis in the male, but had seen it five times in the female.

It will be noticed that, through the medium of the connecting arch, fibres from both nerves reach not only the sternalis *but* also *the pectoralis minor*.

Fig. 4. Very remarkable case of unilateral sternalis in a male. The muscle is split into two parts, and the inner portion has wandered inwards so as to lie over the inner margin of the sternum. ·The recurrent course of the intercostal nerves is very conspicuous.

Fig. 5. Sternalis muscle in a male subject, with all the nerve-relations exhibited. *I.A.T.*, internal anterior thoracic nerve ; *E.A.T.*, external anterior thoracic nerve; *P.M.*, pectoralis minor ; *S.P.*, sternal part of pectoralis major.

THE MOVEMENTS OF THE ANKLE-JOINT. By W. ARBUTHNOT LANE, M.S., F.R.C.S., *Senior Demonstrator of Anatomy, Guy's Hospital; Assistant Surgeon to the Hospital for Sick Children, Great Ormond Street.*

In a recent contribution to the *Guy's Hospital Reports*, 1887, entitled " The Causation, Pathology, and Physiology of the Deformities which Develop during Young Life," I discussed very fully the anatomy and physiology of the movements of the foot, and I believe that I succeeded in placing them on a completely new and correct scientific basis.

In it I argued, that *as the labour changes in the skeleton represent first the fixation, and subsequently the exaggeration of a single normal voluntary movement, so do many of the acquired deformities, such as lateral curvature, flat foot, dorsal excurvation, knock-knee, &c., represent first the fixation, and subsequently the exaggeration of a normal physiological position of rest.*

In this paper I intend to consider in detail the anatomy and physiology of the ankle-joint. I can, perhaps, best do this by quoting from the last edition of Quain's *Anatomy* the movements which are said to take place between the astragalus and the tibia and fibula, since that text-book may be regarded as best representing the teaching of the present day, and I will then attempt to show that the description is incorrect.

The acceptance as fact of the principles laid down in it has led to erroneous methods of diagnosis and of treatment of fractures of the tibia and fibula occurring in the vicinity of the ankle-joint, as well as to many other surgical inaccuracies.

In order to do so I must first state briefly some of the conclusions at which I arrived from the study of the foot, since they bear upon the subject.

They are, *firstly*, that besides the ligaments of the foot already described in works on anatomy, there is another very important one which has escaped the observation of anatomists. It is attached to the inner aspect of the sustentaculum tali

behind, and in front to the inner surface of the tuberosity of the scaphoid, and to the whole of the posterior margin of the upper surface of that bone. One portion of this ligament lies internal to the head of the astragalus, and another portion above the head. Its posterior margin receives the insertion of the deltoid and superior astragalo-scaphoid ligaments, these being attached but indirectly to the scaphoid.

This ligament I have named the *superior internal calcaneo-scaphoid ligament*, on account of the position it occupies with regard to the head and neck of the astragalus. Since it lies in two planes, the direction of its fibres differs. Those in the vertical portion are directed upwards and forwards, while those which lie above the head of the astragalus run outwards and forwards.

That part of the superior internal calcaneo-scaphoid ligament which is in relation with the inner surface of the head of the astragalus is always very thick, and in some cases is enormously so. It is frequently a quarter of an inch in thickness, and cartilaginous and gritty on section. *The tendon of the tibialis posticus muscle lies on the inner surface of this ligament.*

Secondly, that the inferior calcaneo-scaphoid ligament is a much less important structure than the preceding. As compared with it it is comparatively thin. Behind it is attached to the fore part of the sustentaculum tali, and in front to the posterior margin of the lower surface of the scaphoid. Its fibres are directed obliquely inwards and forwards, its inner margin being parallel to and in contact with the lower margin of the superior internal calcaneo-scaphoid ligament, with which it is often continuous, and its outer margin with the short calcaneo-cuboid and external calcaneo-astragaloid ligaments. The *body of the tendon of the tibialis posticus bears no relationship to this ligament,* though the process which passes backwards and slightly outwards from its posterior margin to the sustentaculum tali lies immediately beneath it. The head of the astragalus lies upon its upper surface.

Thirdly, that the external calcaneo-scaphoid ligament is triangular in form. Its apex is attached to the upper surface of the greater process of the os calcis, and its base to the junctions of the posterior margin of the lower and outer surfaces of

the scaphoid. The fibres forming its inner margin run parallel to those of the inferior calcaneo-scaphoid ligament, while those forming its upper or outer margin run forwards and upwards. This ligament opposes any displacement outwards or inwards of the scaphoid, when that bone is rotated upon an antero-posterior axis.

It is obvious, therefore, that the os calcis is connected to the scaphoid by a capsule, which is complete everywhere except above and externally, the superior astragalo-scaphoid ligament filling in the interval between the superior internal and the external calcaneo-scaphoid ligaments. The fibres forming this capsule are arranged very obliquely in relation to an antero-posterior axis passing through the head of the astragalus, and their direction of obliquity is such that, if the scaphoid be rotated by raising its tuberosity, the longitudinal extent of the ligaments connecting it with the os calcis is diminished, while, if the scaphoid be rotated in a reverse direction, their antero-posterior measurement is increased.

On the contraction of the tibialis posticus muscle the astragalus is displaced a little upwards and backwards by the shortening of the calcaneo-scaphoid ligaments. At the same time, the traction exerted by these three ligaments, and the process of the tibialis posticus which is inserted into the sustentaculum tali, draws the os calcis inwards and upwards with the scaphoid.

The traction exerted by the tibialis posticus upon the scaphoid is transmitted anteriorly and laterally to the adjoining bones. The oblique fibres of the short calcaneo-cuboid ligament prevent the inward displacement of the cuboid from off the anterior surface of the os calcis, while it is assisted to some extent by the long plantar ligament in retaining the opposing surfaces of these bones in contact. The same principle of limiting movement is made use of in the calcaneo-cuboid articulation as is utilised in the sacro-iliac joint, namely, the apposition of irregularly concavo-convex surfaces, any movement between them being followed by their necessary separation, this being limited and opposed by strong, dense ligaments. The slight separation of the cuboid and os calcis, produced by the contraction of the tibialis posticus, causes, by means of the long plantar ligament, an increase in the convexity of the outer arch.

The contraction of the tibialis posticus muscle produces an increased convexity of both longitudinal arches, and more especially of the inner, also a movement of those arches inwards around an axis which passes from behind, forwards, inwards, and downwards through the astragalus.

I have called this movement *adduction of the longitudinal arches, or of the foot, upon the astragalus.* A movement termed *inversion of the foot* is described in the text-books. I think it is obviously the movement I have explained above, though it is described somewhat briefly and very incorrectly by the authors of those works. For instance, I find in Quain, vol. i. p. 185, the following:—

" The navicular and cuboid bones can be moved downwards and inwards, or upwards and outwards, over the fore part of the astragalus and calcaneum respectively. It is in these articulations mainly that the movements known as *inversion* and *eversion* have their seat. In inversion the fore part of the foot is depressed and carried inwards, the longitudinal arches are increased, and the outer margin of the foot descends more than the inner, so that the sole is turned to some extent inwards. In eversion these actions are reversed, and the foot resumes its normal position. . . . . . Inversion of the foot is always associated with extension, and eversion with flexion of the ankle-joint."

I will only state here that I see no reason for the last assertion, and would refer the reader for full details to my paper in the *Guy's Hospital Reports.* Before proceeding further, I will again quote from Quain's *Anatomy,* vol. i. p. 170, from the movements of the ankle-joint:—

" The movements of the ankle-joint are mainly those of flexion and extension of the foot, the direction of those movements being determined by the shape of the articular surfaces. The external border of the superior cartilaginous surface of the astragalus is curved and longer than the internal border, and hence extension of the ankle-joint is accompanied with a slight inward movement of the fore part of the foot. The horizontal surfaces of both the tibia and astragalus are broader in front than behind; hence in complete extension of the ankle the narrow part of the astragalus is brought into the widest part of the space between the malleoli, and a certain amount of lateral motion is allowed under influence of external force; whereas in complete flexion, as when the weight of the body, with fully bent knees, is supported on the toes, the broad part of the surface of the astragalus is pushed back in the narrowest part of the space, and the inferior extremity of the fibula is pressed upon, so as to stretch the ligaments between it and the tibia, and thus to prevent lateral move-

ment of the joint, and give it at the same time a certain amount of spring. There appears to be no other movement between the tibia and fibula ; these bones being bound together at their lower ends with remarkable firmness."

The above includes the whole of the description of the movements of the ankle-joint, and there is *no portion* of it to which I cannot take exception, and *which, I think, I can show to be absolutely incorrect.* With regard to the first statement, I hope to show that very little lateral movement can take place between the astragalus and the tibia and fibula in the vigorous adult subject in any position of the ankle-joint. I will first call attention to the second sentence, namely, to the description of the upper and outer articular surfaces of the astragalus, since I believe that it is absolutely incorrect, and that the deductions derived from it are also equally unfounded.
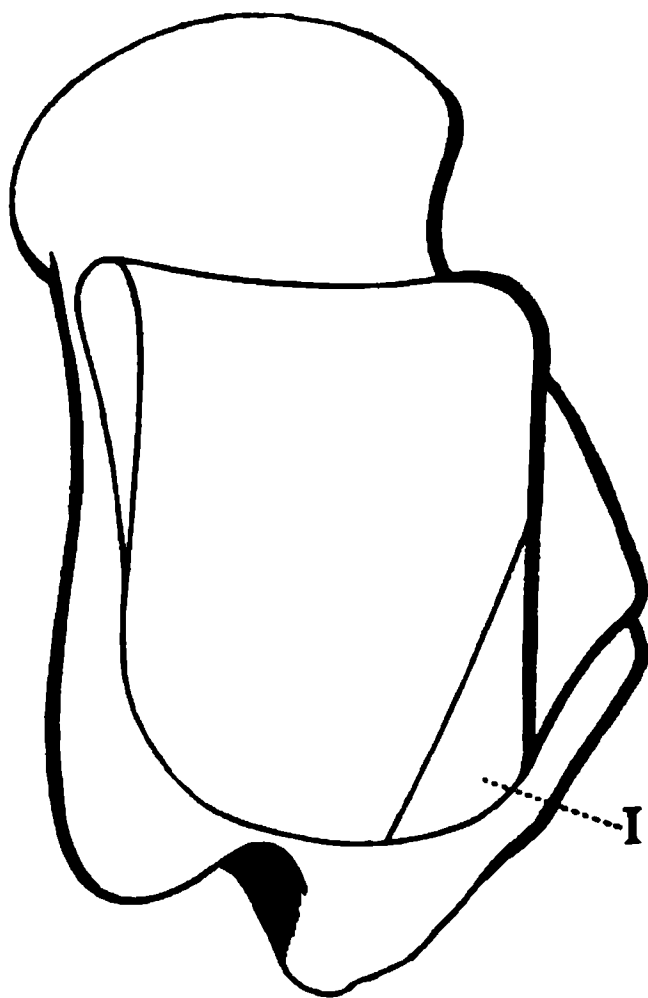
Fig. 1.—Ankle-Joint.

As the point which I wish to demonstrate is but feebly marked on the dry bone, I have represented the upper surface of a recent astragalus diagrammatically in fig. 1, since the articular surfaces are much more clearly defined when covered by cartilage.

The outer border of the superior cartilaginous surface of this

bone is said to be curved, and a superficial examination of the dry bone might lead one to suppose this statement to be correct, but in the recent state it is at once obvious that what appears to be the direct prolongation, backwards and inwards, of the outer margin of the superior articular facet, is merely the inner boundary of a special undescribed triangular facet, which I have indicated by the numeral I in the diagram. This triangular facet is limited externally by what is the true outer border of the upper surface of the astragalus, so that it is consequently but a subdivision of it, and not a portion of the fibular facet, as the descriptions in works on anatomy would lead one to suppose. According to the account of this bone in Quain's *Anatomy*, this triangular facet must be included in the outer surface of the astragalus, since the latter surface is said to be separated from the upper by the so-called oblique backward prolongation of its outer margin.

To describe the articular surface of the astragalus more accurately, one should describe a triangular area as being cut off from the posterior and outer part of its upper surface. This portion looks obliquely backwards, outwards, and slightly upwards. The apex of the triangle is directed forwards, and corresponds to a point considerably in front of the centre of the outer margin of the upper surface of the bone, its inner margin passes obliquely backwards and inwards to the posterior limit of the articular surface, while its outer boundary is formed by the prolongation directly backwards of the outer margin of the tibial facet.

The anterior extremity of the outer border of the tibial facet on the astragalus is on the same transverse vertical plane as that of the inner margin. The borders of the upper surface, including, of course, the triangular area to which I have called attention, run parallel, or nearly so, to one another as far back as the posterior extremity of the inner one, the outer being prolonged for nearly a quarter of an inch beyond the inner. In some bones, as in that from which I traced fig. 1, these borders run quite parallel to one another, but in a larger proportion the interval between the posterior extremity of the inner and that point in the outer border in the same vertical transverse level is less than that between the anterior terminations of these borders by about $\frac{1}{16}$th to $\frac{1}{19}$th of an inch.

The next question which arises is—What function does this triangular area perform ? or, putting the question in another way—What are the factors which determine its formation ? In order to answer this question, I must digress for one moment in order to consider certain anatomical details.

Quain describes the anterior and posterior ligaments of the ankle-joint as " merely scattered fibres in front of or behind the joint; those of the posterior are weak, and principally transverse."

As regards the posterior ligament, the portion of the above description which refers to it is most incomplete and incorrect.

Quain describes a *transverse* or *inferior tibio-fibular ligament* as " a short band of yellowish fibres, under cover of the posterior ligament; it runs horizontally from the hinder border of the lower articular surface of the tibia to the contiguous part of the external malleolus, and closes the angular interval between the bones."

I would point out that a long and narrow bundle of ligament does exist in the position described by Quain; but when cleaned out and exposed as a separate ligament it is loose and flaccid, and in such a condition cannot perform any useful function.

I would describe this band of fibres as only a portion of the posterior ligament of the ankle-joint. This latter structure is, in my opinion, a very distinct and important one. It is attached externally to the fibula in the interval between the attachments of the posterior inferior tibio-fibular ligament and the posterior fasciculus of the external lateral ligament. Long bands of dense fibrous tissue extend from the malleolus obliquely outwards and upwards, to be attached to the posterior inferior margin of the tibia; others pass outwards and downwards, to be attached to the posterior surface of the astragalus; and others, which are less strong, run inwards, and blend with the posterior border of the deltoid or internal lateral ligament.

These radiating fibrous bands are connected together to form a single complete ligament, which covers in the ankle-joint posteriorly.

The upper margin of this ligament is practically continuous with the posterior inferior tibio-fibular ligament, and its lower limit with the posterior fasciculus of the external lateral ligament.

On flexing the ankle-joint, the posterior ligament, which appears to be somewhat elastic, is made tense, and opposes and tends to limit flexion. While the joint is being flexed, the posterior ligament, together with the posterior inferior tibio-fibular and the posterior portion of the external lateral ligament, rest and play upon the triangular area which I have described as being present in the upper articular surface of the astragalus. These ligaments are separated from the remainder of the superior articular surface of the astragalus by a distinct interval.

Careful examination will show that this triangular facet is produced by the habitual pressure exerted by the ligaments upon the bone in flexion of the ankle-joint; also, that however extreme be the position of flexion, yet *the ligamentous facet*, if I may so term it, never articulates with the articular surface of the tibia or fibula.

The plane of the facet on the inner surface of the astragalus lies in a double incline, since it runs forwards, downwards, and inwards, the direction of its surface being inwards, upwards, and backwards. The inward slope is exaggerated in the lower and anterior portion of the facet.

Though the plane of the triangular facet on the outer surface of the astragalus does not deviate continuously from the vertical, it presents a slight convexity from before backwards. From a study of the form of the articular surfaces of the astragalus, and especially of that of its inner surface (and not from any supposed curvation of the outer border of the inferior articular surface of the bone), it would appear that, if the inner facet remained in intimate apposition with the corresponding articular surface on the internal malleolus in all positions of the ankle-joint, as the ankle-joint passes from a position of complete flexion to one of complete extension, the astragalus should move in an oblique and not in a vertical plane, its head passing outwards in the former movement and inwards in the latter. I have, however, carefully observed the variations of the position of the astragalus in the various movements of flexion and extension, and have been unable to detect any deviation from the vertical. The reason of this is, that in extension of the ankle-joint the astragalus is separated by an interval from the inner malleolus. This I will describe more fully at a later stage of this paper.

I will now pass on to the third statement in the description of the movements of the ankle-joint in Quain's *Anatomy*. Since the borders of the upper surface of the astragalus lie almost if not quite parallel to one another, the upper surface is practically of equal breadth as far back as the posterior extremity of the inner border. Below and behind this point there is a prolongation of the tibial and *ligamentous* facets, which is inclosed between the posterior margin of the superior articular surface and its outer margin.

If we examine the movements of the ankle-joints which are possible between the astragalus and the tibia and fibula in the dried skeleton, we would apparently be able to verify the remainder of Quain's description, commencing, " Hence, in complete extension of the ankle-joint, ... a certain amount of lateral movement of the astragalus is allowed under the influence of external force," &c.

As, however, it is quite possible that the presence of the somewhat complex and very incorrectly described ligaments of the ankle and tibio-fibular articulations may influence the apparent mobility of the astragalus in the recent subject, let us appeal to it. If we take the leg of a vigorous adult body, from which the muscles have been removed, and attempt to rotate the astragalus in a horizontal plane upon the tibia and fibula, *while the ankle-joint occupies a position intermediate between complete flexion and extension*, we find that it is possible to displace the head a little inwards and outwards; that when the head is displaced inwards the posterior inferior tibio-fibular ligament is rendered tight, the anterior inferior tibio-fibular ligament is relaxed, the fibula is rotated slightly upon its vertical axis, and the posterior deep portion of the deltoid ligament is made tense. If the head of the astragalus be displaced outwards, the anterior inferior tibio-fibular ligament, the anterior portion of the deltoid ligament, and the posterior fasciculus of the external lateral ligament are put on the stretch, while the fibula is rotated slightly on its own axis in a direction the reverse of that in the preceding experiment.

If we now *flex the ankle-joint completely*, the outer malleolus is slightly raised and displaced a little outwards. The fibula undergoes a slight rotation on its own axis, the anterior margin

of the malleolus being separated from the tibia by a greater interval than the posterior. In fact, the anterior ligament is rendered very tense, while the posterior ligament is very slightly so. The external malleolus is raised from the horizontal level which it occupies when the erect posture is assumed.

Without going further, it is obvious that *the astragalus is not fixed immovably as regards the possibility of rotating it in a horizontal plane solely by the strain exerted by the ligaments connecting the tibia and fibula*, and that the movements which are permitted in the tibio-fibular joints are not simply those of separation and approximation.

The former fact may be demonstrated more completely by dividing the ligaments which connect the astragalus to the tibia and fibula, and, after placing the astragalus in the position which it occupies in complete flexion of the ankle-joint, attempting to adduct or abduct the head of the astragalus from a vertical antero-posterior plane. It will be found that the strain sustained by the tibio-fibular ligaments is insufficient to prevent a considerable amount of lateral motion of the astragalus. The fixation of the astragalus in a horizontal plane in extreme flexion of the ankle-joint depends upon the enormous strain sustained by the back part of the deltoid ligament and by the posterior fasciculus of the external lateral ligament. If, in the dead body, the posterior ligament be removed and the ankle-joint be flexed completely, it is seen that the anterior inferior tibio-fibular ligament prevents the separation of the anterior margin of the malleolus from the tibia, that the posterior portion of the deltoid ligament exerts an immense traction in a forward and inward direction upon the back part of the astragalus, fixing it immovably to the inner malleolus, while the equally great strain exerted in a direction inwards and backwards by the posterior fasciculus of the external lateral ligament upon the fibula behind its axis of vertical rotation fixes its posterior margin immovably upon the tibia and astragalus.

Therefore, while the anterior portion of the astragalus is fixed between the anterior portions of the malleoli by the strain exerted by the anterior inferior tibio-fibular ligament, its posterior portion is fixed immovably by the strain exerted upon it on either side by the posterior fasciculus of the external lateral

ligament and by the back part of the internal lateral ligament, the former exerting traction upon it in a direction from behind, outwards and forwards, the latter from behind, inwards and forwards.

We see that the ligaments which are chiefly engaged in preventing the separation of the malleoli by the wedge-shaped internal articular surface of the astragalus are the anterior inferior tibio-fibular ligament, the posterior fasciculus of the external lateral ligament, and the back part of the deltoid ligament. The interosseous membrane, the posterior inferior tibio-fibular, and inferior interosseous ligaments take but a very secondary share in this work.

The amount of strain which the ligaments so fixing the astragalus can stand is very considerable indeed, as is demonstrated by the great degree of pressure which is required in order to force the malleoli beyond the anterior limits of the facets on the astragalus. The mechanism which is adopted here is similar to, though not identical in character with, that I have described as being made use of in the sacro-iliac and calcaneocuboid joints.

I would also point out that the position of the ankle-joint which is assumed habitually as its *position of rest*, namely, that which is sustained with a minimum expenditure of muscular energy, *is one of partial flexion.*

In labourers who are in the habit of transmitting much weight through the flexed ankle-joints, I have found very distinct changes in the malleolar articulations, and more especially in the inner one, the anterior margin of the facet on the astragalus being abruptly prominent and lipped, while the opposing margin of the inner malleolus presents corresponding changes.

In the merchant service seamen, the joints of whose foot and ankle allow of a remarkable freedom of movement, there is developed upon the anterior surface of the lower extremity of the tibia an articular surface with a convex upper margin. This surface is continuous with the inferior articular facet upon this bone, and is included within the cavity of the ankle-joint. It articulates in extreme flexion with a corresponding articular surface upon the outer part of the upper aspect of the neck of the astragalus. The mode of causation of this modification in the

form of the ankle-joint is quite obvious from a knowledge of the habits of the individual.

We will now pass on to examine the supposed lateral movement which is said to be possible between the astragalus and tibia and fibula when the ankle-joint is extended completely. If in a leg from which the muscles have been removed *the ankle-joint be extended to its full extent*, and an attempt be made to adduct or abduct the head of the astragalus, it is found impossible to produce any lateral movement of that bone.

This result is obviously quite contradictory to that usually received, which would appear to have been obtained by an analysis of the movements which are possible between the astragalus and the tibia and fibula when cleaned and articulated.

Before proceeding further, I must call attention to another anatomical point which appears to have escaped the notice of previous observers. The astragalus (fig. 1) presents behind its upper articulating surface, on what is described as its posterior aspect, a prominence bounded externally by the oblique groove which lodges the tendon of the flexus longus hallucis. The upper surface of this projection is concave, and is usually continuous by a gradual incline with the upper articular surface of the astragalus, and in some cases it is covered by a prolongation of its covering of articular cartilage. In most cases, however, it is coated with a layer of fibrous tissue and synovial membrane.

In the outer portion of the posterior margin and on the adjacent surface of the astragaloid facet on the tibia, there is a transversely oval facet, to the hinder margin of which the fibres of the posterior inferior tibio-fibular ligament are attached.

In complete extension of the ankle-joint the concavity on the projection on the back of the astragalus comes into contact and articulates with the corresponding little articular surface on the tibia, and with the adjacent portion of the posterior inferior tibio-fibular ligament, and it is this impact of these two opposing surfaces which limits the movement of extension of the ankle-joint. In fact, if the ankle-joint be carefully examined while it is in a position of very complete extension, neither the tibial facet on the upper surface of the astragalus nor the facet on its inner surface are in contact with their corresponding

tibial facets, but the astragalus articulates with the tibia solely by the concave facet on the upper surface of the prominence on its posterior surface. Its outer articular surface is fixed immovably to the corresponding facet on the outer malleolus.

The interval that exists between the opposing surfaces of the tibia and astragalus while in this position is occupied by an interarticular synovial fold, which contains fat and projects from the posterior surface of the anterior ligament of the ankle-joint. In those who habitually perform this movement of complete extension of the ankle-joint this interarticular synovial structure is remarkably well developed.

In a slightly less degree of extension portions of the upper and inner facets on the astragalus come into contact with their corresponding surfaces on the tibia.

In complete extension the outer malleolus is drawn slightly downwards and inwards by the strain exerted upon it by the strong anterior fasciculus of the external lateral ligament, and also inwards by the posterior fasciculus of the same ligament. I would point out here that the latter portion of the external lateral ligament limits and opposes movements both of complete flexion and complete extension of the ankle-joint, for the reason that its fibres occupy a horizontal plane, and the interval between its points of attachment is least where the joint occupies a position midway between complete flexion and extension. Any deviation from this posture, either in the direction of flexion or extension, renders the fibres of this ligament oblique, separating its bony attachments and making it tense. In extreme flexion of the ankle-joint the posterior fasciculus is rendered tense, and exerts a traction upon the lower end of the fibula in a direction inwards, backwards, and downwards, while in extreme extension the same band of fibres tends to draw the malleolus inwards, backwards, and upwards. In the latter position the strain exerted by the tense anterior fasciculus of the external lateral ligament in a direction from above downwards, forwards, and inwards displaces the fibula slightly downwards. This movement of the fibula is limited by all the tibio-fibular ligaments and by the posterior fasciculus of the external lateral ligament. In extreme extension the anterior portion of the deltoid ligament is rendered very tense.

Now, it is obvious that in extreme extension the astragalus is retained, as regards rotation in its horizontal plane, immovably upon the external malleolus by the ligaments which connect these bones together, namely, by the anterior and posterior fasciculi of the external lateral ligament, the fibula being fixed immovably by the strain exerted upon it by the several tibiofibular ligaments, by the impact of the prominence on the back of the astragalus upon the lower end of the tibia, and by the strain exerted upon the astragalus in a direction backwards and inwards by the anterior portion of the deltoid ligament.

To put this in another way. The head of the astragalus cannot be displaced inwards owing to the strain exerted upon it in an outward and backward direction by the anterior fasciculus of the external lateral ligament. It cannot be displaced outwards on account of the strain exerted upon it by the anterior portion of the deltoid ligament in a backward and inward direction. The fibula is fixed immovably upon the astragalus by the strain exerted in an inward, downward, and forward direction by the anterior fasciculus of the external lateral ligament, and in an inward, backward, and upward direction by the posterior fasciculus of the same ligament. The fibula is fixed upon the tibia directly by the ligaments which connect them, all of which are rendered tense by the tractions exerted upon the outer malleolus by the two fasciculi of the outer lateral ligament, and indirectly by means of the fixation of the astragalus upon the tibia.

It is also worthy of notice, that the several flexor muscles and the peroneus longus and brevis are attached to the fibula, and exert traction upon it in such a manner as to assist the ligaments very materially in fixing the fibula upon the tibia when the body is retained erect upon the fully extended foot, by opposing the displacements of the fibula which the traction tends to produce. The shape of the fibula and the direction of its several surfaces lend themselves very readily to this purpose. Practically I suppose we may assume that the peculiar form of the human fibula has arisen in consequence of the function of rotating the fibula, &c., which the flexor and peronei muscles attached to it perform, and by means of which the ankle-joint is strengthened and rendered secure.

Much of the error into which anatomical and surgical text-books have fallen with regard to the movements permitted in the ankle-joint of the vigorous adult subject is due also to the great freedom with which the foot may be adducted or abducted upon the astragalus when the ankle-joint is extended, and to the inability to perform this movement when the ankle-joint is forcibly flexed. The reason is that in the latter case the astragalus is fixed, and the astragalo-scaphoid capsule and the plantar ligaments are rendered extremely tense by the force exerted in forcibly flexing the ankle-joint, and it is therefore impossible to adduct or abduct the foot in the manner I have described in the *Guy's Hospital Reports*, 1887, and to which I would refer for full particulars. I would also call attention here to another contribution contained in the same volume of the *Reports* (" An Undescribed Fracture of the Lower End of the Tibia or Fibula, or of Both Bones, which cannot be recognised during lifetime "). In it I showed that excessive rotation of the astragalus in a horizontal plane might produce fracture of one or both bones of the leg, the bones yielding rather than the ligaments which are attached to them. In the large majority of cases the fragments presented no displacement whatever. The reason of this is obvious, if the seat of the fracture or fractures be carefully observed.

ACCOUNT OF A TERATOMA SPRINGING FROM THE SPHENOID OF A CALF, WITH THE RESULTS PRODUCED BY THE TUMOUR. By Bertram C. A. Windle, M.A., M.D. Dubl., *Professor of Anatomy in the Queen's College, Birmingham.*

THE head of a calf with a cleft palate and other deformities having been exhibited at a meeting of the Odontological Society by my friend and colleague, Mr John Humphreys, L.D.S., was kindly handed over by him to me for dissection. The animal to which it belonged was otherwise perfectly healthy and normally formed, nor was anything unusual noticed with regard to its birth, or the membranes connected with it. It became necessary to kill it, because it was unable to swallow milk, which when taken into the mouth ran out of the nostrils.

I must express my thanks to my friend Mr Hodson for the faithful drawing which represents the parts concerned.

Description of the Specimen.—Viewed with the mouth closed the obvious external defects were a failure of union of the two halves of the inferior maxilla with a cleft of the floor of the mouth and soft parts generally, extending about 5·0 to 6·0 cm. backwards, the entire length of the jaws being 21·0 cm. An additional incisor was also present (*a*), placed on the inner extremity of the left half of the inferior maxilla. This tooth had no bony connection, being bound to the jaw by gum alone. It also differed in shape from the other incisors, being folded longitudinally upon itself, so that its crown presented a horse-shoe-like appearance.

On opening the mouth a fissure of the palate came into view (*b*), extending through all the posterior part, but not through the front of the premaxillæ. On the left side it passed into the anterior palatine foramen; on the right it was shut out from this opening by the fusion of the palatine process of the superior maxilla with the premaxilla and the vomer (*c*). The fissure on the left side measured 14·0 cm., on the right 8·0 cm., in length, the entire breadth posteriorly being 2·8 cm.

The parts connected with the tongue were much altered. On either side could be seen the two halves of that organ, which was evidently deeply cleft (*d, e*). These were quite normal in appearance, each resembling a miniature calf's tongue. The right half (*d*) measured 12·0 × 4·0 cm., the left (*e*) 12·5 × 2·5 cm. Between these two there was a central elevated mass (*f*) which rested upon the posterior and mesial parts of the two halves of the tongue, projecting up between them, and connected with the floor of the mouth. In its anterior part could be felt a large hard substance. On closing the mouth it was seen that this fleshy mass exactly fitted into the cleft in the palate posteriorly, though it did not reach quite sufficiently far forward to fill its anterior portion. On its upper surface it was smooth, covered with mucous membrane from which grew some hair, and thus contrasted markedly with the two halves of the tongue lying on either side of it.

Anteriorly it abutted on the floor of the mouth, and here a portion of the hairy skin passed in through the cleft, and clothed the inferior parts of its left side. Posteriorly (*f'*) this mass was attached to the floor of the skull, between the halves of the cleft palate, in a manner shortly to be described, so that it formed a kind of bridge over the entrance to the trachea and œsophagus. It would consequently only be possible for food or air to pass downwards by making their way under the posterior extremity of the mass. On the left side of this fleshy mass, and connected with it, lying upon the left half of the tongue, was a hard bean-shaped nodule (*g*), 2·4 cm. in length, 1·8 cm. in breadth, and 0·9 cm. in depth.

A dissection was made through the floor of the mouth from below, with the following results. The structures passed through presented nothing noteworthy until the suprahyoid region and the root of the tongue were reached. The dissection thus made showed that the central tumour (*f*) had no connection whatever with the halves of the tongue, but was attached to or imbedded in the floor of the mouth, projecting upwards from between them. When the attachment between the tumour and the floor of the mouth was severed by a semi-circular incision, and the tumour turned back, it became evident that the tongue was deeply though not completely cleft,

Calf's head with basicranial teratoma.   The mouth of the calf is represented as widely opened.

a, Supernumerary incisor.

b, Palatine cleft.

c, Vomer.

d, e, Right and left halves of the tongue.

f, f', The central tumour.   The dark pit behind f' is a rent in the mucous membrane of the roof of the pharynx, caused by the tearing of the pedicle when the jaws were opened.

g, The lateral dentigerous tumour.

presenting a horse-shoe-shaped appearance. In order that the tumour might be examined, the inferior maxillæ, tongue, and parts attached were removed from the skull. It was then, for the first time, seen that the tumour had been connected posteriorly by bony union with the basi-sphenoid. The portion of bone passing from the skull to the tumour was slender, and had been fractured in opening the jaws, but the rough broken surfaces could easily be placed together and fitted exactly. The periosteum of the sphenoid was continuous with that covering the bone, and passed along it into the tumour. The greater part of this latter consisted of irregularly arranged bundles of muscular tissue, with connective tissue and substances of a glandular appearance. The parts were not in a state very favourable for microscopic examination, and none was made. In its centre were two pieces of bone bound together by ligaments. Of these the smaller and posterior, which was shaped like an arrow-head, had been joined by its point to the basi-sphenoid. The points of the bifurcated extremity were attached to the larger and central bone by two distinct and strong ligamentous bands. The length of the smaller bone was 2·0 cm. The larger bone was 5·0 cm. in length, and spindle-shaped. It was sawn into a series of longitudinal sections, and was cut with some difficulty, being excessively dense, resembling ivory in its hardness. When thus divided it was seen to consist of two distinct portions : (1) an upper thin elongated bone, comparatively soft, but still of considerable density, which formed a cover for and arched over (2) the larger part of the bone, which was white, excessively dense and hard, and contained near its centre an irregular cavity. In one small cavity between the two portions of bone lay what appeared to be undoubtedly a small denticle. An examination was next made of the rounded tumour (g).

This was also sawn into longitudinal slices, though it would, as subsequently appeared, have been better examined by cutting off the shell. Its interior contained one or probably two teeth of a molariform appearance. Its wall consisted of a layer of mucous membrane covering a shell partly formed of fibrous tissue, but chiefly of slim egg-shell-like bone.

The interior of the skull was then examined, and the brain, though not well preserved, was apparently quite normal, as also

was the hypophysis. On removing this last, a deep pit in the substance of the basi-sphenoid came into view, capable of admitting an ordinary probe, and passing nearly to the under surface of the bone. This pit was placed immediately above the site of attachment of the bony pedicle of the tumour, but did not apparently extend into it. Such is the description of the specimen. I now propose to consider its several parts in order.

Tumour.—In the title of this paper I have described the tumour as a teratoma, and it may be placed in the group allied to that form of parasite known as epignathus. In thus placing it I follow the view expressed by Zeigler,[1] that the difference between a parasitic foetus and a teratoma is one of degree, and depends upon the amount of development exhibited. Förster[2] takes the same view when he says that unless the tumour contains some true organ, such as an extremity or intestine, it must not be looked upon as a case of foetus in foetu. The following cases from the literature of the subject bear most nearly upon my specimen.

Professor Hill,[3] in a paper on the dissection of an epignathus, describes a tumour attached to the basi-sphenoid of a child, which contained various dermoid structures and an embryonic form of liver, by virtue of which it may be elevated from the rank of a teratoma to that of a parasite.

Abraham[4] has described a tumour covered with pilose skin, which contained dermoid structures and nodules of cartilage. This "tumour grew from the top of the pharynx, near to the basilar suture, *i.e.*, in the line of the epiblastic ingrowth, which in the developing foetus went to form a portion of the pituitary body." On which he remarks, "Have some of these epiblastic cells remained and multiplied with epidermic character ?"

Arnold[5] describes a congenital lipoma of the tongue and pharynx which perforated the basi-sphenoid, so that a portion as large as a walnut lay in the interior of the cranium. The

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[1] *General Pathological Anatomy Trans.*, Macalister, p. 36.
[2] *Missbildungen des Menschen*, p. 27.
[3] *Jour. of Anat. and Phys.*, vol. xix. p. 190.
[4] *Jour. of Anat. and Phys.*, vol. xv. p. 244.
[5] Virchow's *Archiv*, Bd. 1. S. 482.

hard and soft palates were both cleft. Besides fat, the tumour possessed hairs and sebaceous glands. In the museum of the Royal College of Surgeons, England, is a somewhat similar tumour to mine, which is thus described:[1]—"The injected head of a human fœtus, with a large lobulated tumour, the remains of a second fœtus, growing from the median fissure of the palate, which has been kept open by it. The tumour projects from the mouth, which it dilates considerably. It is adherent to the right commissure of the lips, and entirely invested the superior maxillary bone of the fœtus." This tumour presented a widely extended mouth in front, the lips and alveoli of which were very distinct. It had a single nostril, with a deep fissure at its inner side, which was probably the remains of the nasal cavity. The bulk of the tumour was made up of firm vascular fat. It contained fifty-nine ossicles, most complex in form, which were closely packed together. Only one of these resembled any normal bone; this resembled the lamina of one of the cervical vertebræ. "The most remarkable point in this specimen is that the lips and alveoli only are well developed on the tumour, as if its position had determined the nature of the part developed."

In a recent paper, Arnold[2] has collected all the cases which he could discover of pilose tumours growing from the pharynx. Thirty-eight cases are tabulated, in twelve of which a cleft of the palate existed and in two a bifid tongue. Some of these are only described as springing from the pharynx, others from the hard palate, a few which follow arising from the basi-sphenoid.

Sonnenburg[3]—The hard and soft palates as well as the uvula were cleft, and the tumour was also connected with the tongue.

Baart de la Faille[4]—The pedicle passed through the floor of the sella turcica, and was there lost. The hypophysis cerebri was absent.

Breschet[5]—The tumour sprang from the basi-sphenoid.

[1] *Teratological Catalogue*, No. 131, pp. 32, 33.
[2] Virchow's *Archiv*, Bd. cxi. S. 176.
[3] *Deutsches Arch. für Chirurg.*, Bd. v.
[4] Quoted by Ahlfeld, *Arch. für Gynäk.*, Bd. vii.   [5] *Ibid.*

It is, I think, allowable to conclude, from a consideration of these cases, that the main origin of my tumour, as shown by its bony pedicle and the pit in the floor of the sella turcica, was from the basi-sphenoid, and that it may be therefore described as an epignathoid teratoma, if such a phrase may be coined. It will be observed that in many of the cases given above clefts of the palate and tongue coincided with, and were probably produced by, the tumour, and I believe that the clefts in my case had a similar origin. The production of clefts of this kind in a similar manner has been remarked by other authors. Butlin [1] says that in cases of bifid tongue, where the cleft is very long, it is often associated with the development of a tumour in the floor of the mouth; and M. Pollusson,[2] in the *Lyon Medical*, has recorded a case of a cystic tumour, associated with incomplete development of the structures formed by the branchial arches, the malformations being excentric hypertrophy of the lower jaw and atrophy of the tongue.

Palatine Cleft.—I have been able to refer to the following cases of cleft palate in animals. The museum of the Royal College of Surgeons contains specimens of skulls of lions born in the Zoological Gardens, many of whom are thus affected. It also possesses two calves' skulls with cleft palates. Fleming [3] describes, apparently as rare, a case of a thoroughbred foal in which there was a cleft palate, but otherwise, so far as I have been able to consult them, veterinary works are silent on this point.

Gurlt,[4] in describing a case of " schistocephalus, schisto-gnathus, et schistoglossus," speaks of this condition as very rare, he having only seen it twice—once in a calf and once in a pig. So far as concerns the clefts in the former, he says—" The two halves of the inferior maxilla are completely separated, and on each is found one-half of the anterior part of the tongue, the root being completely separated from both of these, and lying 1¼ inches further back attached to the hyoid bone. Here the mucous membrane passes directly into the hairy skin. The

[1] *Diseases of the Tongue*, p. 21.
[2] As quoted in the *Lancet*, September 20, 1884.
[3] *Veterinary Obstetrics*, Lond., 1878, p. 93.
[4] *Thierische Missbildungen*, Bd. 20, Art. 48.

separated root of the tongue is innervated by the hypoglossal and glosso-pharyngeal nerves, the anterior halves each receiving the lingual branch of the 5th nerve of its own side. The lingual artery supplies the root, the facial the halves of the anterior part." The hard palate was also cleft in this case, the fissure not extending through the anterior part of the intermaxillary bones. Gurlt also mentions a similar case described by Berthold,[1] in which the inferior maxilla, tongue, and floor of mouth were cleft.

Professor Cleland[2] has called attention to the fact that in five out of six cases of monstrous kittens, the palate was widely cleft, and the tongue lay in the nasal cavity. In one of these cases there were two heads, one of which had a cleft palate, the other an imperfect development of the vomer. The remaining cases were kittens with parasitic twins, the former presenting cleft palates. I have examinèd a similar specimen of a puppy having a widely cleft palate. Until further observations have been made, for there is no note on the point in connection with other specimens of the kind in the museum catalogues to which I have referred, it is impossible to say with what constancy cleft palate coexists with heterologous union, but the subject is one well worthy of further attention.

Albrecht,[3] Kölliker,[4] and Turner[5] have dealt with the bearing of cleft palate upon the development of the intermaxillary bone. Albrecht believes this bone to consist of two parts on either side, which he names endognathion (mesial) and mesognathion (lateral), the fissure in certain cases of cleft palate passing between the two. With this view Kölliker does not agree. Turner records a number of observations which harmonise with Albrecht's theory. In a recent paper Biondi[6] has returned to the question and accumulated much fresh evidence, which, to a certain extent, favours Albrecht's view. He has observed three cases of cleft

[1] *Acta Acad. Cæs. Leopold. Carol. Natur. Curs.*, vol. xix. P. i. p. 319, Tab. xxix. In this paper is also an account of a similar case quoted from Rudolphi.

[2] *Journal of Anat. and Phys.*, vol. viii. p. 250.

[3] *Sur les 4os intermax.*, &c., and other papers, for which *cf.* Turner (⁵).

[4] *Ueber das os intermaxillare*, &c., *Nov. Acta der Leop. Carol. Ak.*, Bd. xliii.

[5] *Jour. of Anat. and Phys.*, vol. xix. p. 198.

[6] Virchow's *Archiv*, Bd. cxi. 3, 125.

palate in calves in the Berlin Veterinary School, two right-sided and one double. In the specimen which he figures the fissure does not affect the superior maxillæ, but the anterior parts of the premaxillæ passing between the outer portion (apophysis nasalis) and the inner (apophysis palatinus). He believes that each intermaxillary bone consists of two parts, though these parts do not bear the relation to one another which Albrecht described. A central portion (metopogenous) is placed in the middle on either side, but does not reach forward to the front of the face, being covered by the lateral (gnathogenous) portion. In certain cases a cleft passes between these two, and then the central bone is uncovered and appears on the surface of the skeleton of the face. He mentions cases of cleft palate in animals examined by him in the Dresden Veterinary School, and quotes others described by Albrecht[1] and Johne.[2] In the skull of an antelope which he figures there are on either side visible remains of a suture (interalveolar) between the two parts of the intermaxillary bone, and a similar suture can be faintly traced on either side in my calf's skull.

Inferior Maxilla.—Separation of the two halves of the inferior maxilla may happen, though rarely, in man (Vrolik[3]); according to other authors (Förster,[4] Humphry[5]) cleavage is only partial or does not occur at all. In one case at least of which I have met with an account,[6] cleft of the tongue and of the inferior maxilla coexisted in a child which survived its birth fifteen days. The frequency of the occurrence of supernumerary teeth in connection with cleft of the superior and intermaxillary bones has been dealt with at length in papers already quoted, and is now an established fact. It is therefore interesting to find an additional incisor in the cleft between the two halves of the inferior maxilla in my case. In Berthold's case, already mentioned, there are on the right side 3 incisors, on the left 4, the fourth being attached in a manner similar to that described in my case.

[1] *Zool. Anzeiger*, 1879, S. 209.
[2] *Bericht über das Veterinärwesen in Königreich Sachsen pro* 1883.
[3] Todd's *Cyclopædia*, art. " Teratology," p. 954.
[4] *Op. cit.*, p. 99.
[5] *Human Skeleton*, p. 292.
[6] *Nouveau Dict. de Méd. et de Chir.*, vol. xx. p. 130.

Tongue.—As already mentioned, Butlin alludes to the con-
dition known as bifid tongue, and Ahlfeld [1] has observed cases
of this deformity coexisting with deep clefts of the face and with
epignathus.   My colleague, Professor Barling,[2] recently described
a remarkable case of this deformity in a child aged ten months.
" The tongue was bifurcated as far back as its middle, the two
halves diverging, and leaving a V-shaped gap, at the apex of
which, as well as to the floor of the mouth and inferior maxilla,
the median lobe was attached.   The bulk of the lobe, which was
as large as the end of one's thumb, projected between the lips,
dragging with it the end of the tongue proper." The central
portion was removed and found to consist of muscular tissue
resembling that of the tongue.   " There was a cleft of the palate
which implicated all the soft and most of the bony vault, but
the premaxillary bone was of good size and in proper position."

The various cases of divided tongue which have just been
described, with others not here alluded to, are somewhat difficult
to explain from the generally received account of the normal
development of that organ.

According to His,[3] and the same view appears to be accepted
by Wiedersheim [4] and O. Hertwig,[5] " the tongue in man has
a double origin.   From the anterior region of the ventral
space (mesobranchial area), between the visceral arches of an
early embryo, a small round projection (tuberculum impar) is
formed; behind this are a pair of folds (furcula), which eventu-
ally will form the epiglottis.   The ventral portions of the second
and third arches grow towards their fellows of the opposite
side between the tuberculum and the furcula.   The basal
growths of the arches form the roots of the future tongue, and
unite together behind the tuberculum impar; the median pit
between these structures is the rudiment of the median lobe of
the thyroid body.   The tongue is formed by the fusion of the
two roots with the tuberculum."   Mall [6] arrives at somewhat

[1] *Die Missbild. des Mensch. Abschn.*, i. S. 118.
[2] *Brit. Med. Journal*, Dec. 5, 1885.
[3] *Anat. Mensch. Emb.*, pt. iii. S. 64-72.   The quotation is from Professor A. C.
Haddon's *Introduction to the Study of Embryology.*
[4] *Comp. Anat. of Vertebrates*, trans. Parker, p. 225.
[5] *Lehrb. der Entwick. des Mensch. u. d. Wirbelth.*
[6] *Arch. f. Anat. u. Entwick.*, Jahrg. 1887, Hft. 1, S. 30.

similar conclusions with regard to the tongue in the Chick. In dogs Kölliker[1] found the tongue to originate from a simple unpaired body on the inner surface of the three first visceral arches, but chiefly from the first. A single origin, in so far at least as concerns the anterior part, has also been described by Born[2] for the Pig. On the other hand, Dursy,[3] in examining the same animal, appears to have arrived at different results. According to his observations the free anterior portion of the tongue is developed by the union of two bodies, which lie on each side of the middle line on the inner surface of the three first arches, the root of the tongue being formed from the second and third arches.

When we turn to the -teratological condition of bifid tongue we meet with three varieties.

1. More or less complete cleavage into two equal parts, a perfect V-shaped cleft being formed between them.

2. A similar cleavage with the addition of a third lobe at the apex of the V.

3. The remarkable condition met with in Gurlt's calf, where the tongue consisted of three distinct and separate portions, attached to the hyoid bone and the two halves of the inferior maxilla respectively.

It is, as Butlin, remarks, somewhat difficult to form a theory which will account for even simply bifid tongue from the generally received embryological views stated above. It should of course not be forgotten that a bifid tongue normally exists in some Amphibians and Ophidians, and even in the Seal, but I am not aware whether any observations have been made on the development of that organ in these forms. When we consider the remaining two varieties the difficulty of explanation becomes still greater. From Dursy's observations the various forms can easily be explained. If part of each of the lateral portions of the tongue be developed from the first arch of either side, as he supposed, and the central portion from the tuberculum impar, or some similar structure appearing further back, it is easy to understand how hypertrophy of the former,

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[1] *Entwickelungsgeschichte,* p. 844.

[2] As quoted by Haddon and Mall.

[3] As quoted by Kölliker and Mall.

with a want of development of the latter, may produce a bifid tongue of the first kind, and the same condition of the lateral portions, with incomplete development of the median, the second, whilst a failure of the three parts to unite with one another would lead to the third form.

If it is allowable to risk a hypothesis on the data before us, it may be suggested that whilst in most cases the lateral outgrowths may not extend beyond the second arch, as His believes, in others they may, as Dursy observed, reach to the first. Under these circumstances, and given the requisite conditions, whatever they may be, producing a total or partial failure of union, the various forms met with might result. The innervation of Gurlt's case being interesting, and likely to throw light upon the subject, I referred the point to Professor Milnes Marshall, who informs me that the supply to the lateral portions, from the 5th nerve, certainly suggests that the first arch is concerned in their formation.

SCHEMA OF THE CIRCULATION OF THE BLOOD AND LYMPH. By T. CRANSTOUN CHARLES, M.D.,
Lecturer on Practical Physiology, St Thomas's Hospital.

THIS schema has been advantageously employed in teaching students, and in the expectation that it may prove helpful to some other teachers like myself, I have determined to publish an account of it. No doubt, most teachers have schemes of their own, which they may regard as the best. It is not, however, with any desire or intention of supplanting these that I am publishing the present scheme; I do so merely in the hope that it may be more or less suggestive, for, with the exception of the part of it illustrating the circulation of the lymph, I do not put it forward as new or original. But with any other scheme which illustrates the lymph circulation I may say that I am not acquainted; this at least, I think, I may claim to be fairly well demonstrated in the apparatus about to be described.

After a short account of the pieces composing the schema, I shall indicate the experiments I am accustomed to show by its means. These will afford full opportunity to the teacher of explaining the physical principles on which they depend, as well as their physiological bearings. I have found, I may observe, that students gain many advantages by the repetition of the same or kindred experiments, advantages that more than compensate for the additional time required in their performance.

The pieces of the apparatus are the following:—

p, a manometer, consisting of a piece of thick glass fixed vertically in a wooden foot, and supporting on each side a ∪-tube containing mercury. These ∪-tubes may be fixed by means of two elastic bands, as in the figure, which allows of their being shifted up or down if necessary. The vertical glass plate, to which an inch scale is attached, enables the heights of the mercurial columns to be readily compared. The tubes may, if preferred, be permanently fixed with brass clips on the same side of a wooden support. The left arm of the tube (*p'*) requires to be nearly twice as long as its right arm, and a floating marker may be fixed in it; but, for convenience' sake, the arrangement shown in the figure has been adopted, in which a piece

of india-rubber tubing (p') is attached, which prevents the mercury from being jerked out, although, of course, in rising it will compress the enclosed air, and its height be less in proportion.

x, a stand to support some coils of elastic tubing, and carrying three marking levers (h) which rest upon the tubing, being arranged so as to record tracings of wave movements upon the smoked surface of the revolving cylinder (l). This elastic tubing must be very thin; indeed, it is difficult to get it sufficiently thin for the purpose, and the tube u should be wider than the tube v, g, t. The latter is arranged so as to form three coils, and then connected with the resistance apparatus attached to the stand to the right of the revolving cylinder. Two pieces of this tubing are necessary, with one of which the tracings on the cylinder are to be taken after the connections shown in the figure have been made, while the other piece is continuous, and ends in the resistance apparatus without breaks or connections of any kind to interfere with its elasticity. The tracings of the course of waves and their rate of progression can by its means be obtained more accurately.

y, the resistance apparatus, consisting of a Y-tube above and below, one limb of each being connected by a wide thin-walled elastic tube with a screw clip upon it, while the other limb divides into three tubes. The middle divisions of the latter are connected by a continuous narrow tube bearing a clip, and the lateral by narrow elastic tubes, each of which expands midway into a small elastic bag, that is tightly filled with fragments of sponge. The tube u runs from the top of this resistance apparatus to the glass vessel a.

q and r, metallic stop-cock jets inserted into the tubes t and u respectively.

a, a pail or glass vessel to serve as a reservoir for the water that is to act as the circulating fluid.

b, a thick india-rubber bag or bottle (a large Higginson's syringe serves the purpose), which can be compressed by the hand of an assistant, or better, probably, by means of a broad piece of wood hinged to a wooden stool, and with an elongated handle, the elastic bottle being fixed beneath it to the top of the stool.

e, a glass tube ¾-inch in diameter and about 5 feet long.

f, an elastic stopper fitted to the mouth of e, and penetrated by a narrow glass tube drawn out at one end to a narrow orifice.

The next piece of apparatus is to illustrate the lymphatic circulation.

3, a large glass bottle with a wide neck and a much wider opening in its bottom (see 10), the latter being fitted into a wooden base (11), and the aperture in it closed by a sheet of india-rubber tightly tied on. By this means the bottle can be opened widely from below, and the hand inserted so as to adjust the contents as required.

To obtain a water-tight base I have tried several contrivances, but only one of these, in addition to that described above, worked at all well; in this a glass receiver, open at the base with ground edges, was clamped with iron flanges or rings into a grooved wooden base, covered by a thick sheet of rubber. But the bottle now used,

recommended to me by Mr T. Hawksley, can readily be obtained, and is more effective, and easier to work with.

The stopper in the neck may be made of rubber, or of cork that has been boiled for some time in molten wax. In it are three apertures : the central one for a narrow metal tube (7), which gives off three bell-mouthed branches below ; and each of the lateral apertures, for a narrow metal tube dividing at its lower extremity into three branches. Loops of specially prepared intestinal tube connect these branches, as shown in the figure.

4, the wooden base into which the bottle (3) is fitted.

11, vertical transverse section of the above, showing, below 10, the india-rubber closing in the wide orifice in the bottom of the bottle.

8, a small bottle connected to 7 by the narrow elastic tube 6, and to the wide tube 2 by means of 9. In 6 there are inserted two, and in 9 one, forward-opening valve.

The intestinal tubing is thus prepared :—About six feet of fresh sheep's intestine is well washed and placed in a mixture of glycerine (1) and water (3) for a few days ; then divided into three equal lengths, each of which is to be turned inside out, and its mucous membrane carefully stripped off, and then allowed to soak for an hour or so in water containing mercuric chloride ($\frac{1}{4}$ per cent.). The pieces are subsequently immersed in dilute spirit for a week, after which they are ready to be tied on the tubes. When not in use they should lie in spirit, which can be introduced in a wide-mouthed jar inside the large glass bottle. And it may here be remarked that it is advisable to keep all the elastic tubing immersed in water when not being employed ; it thus lasts much longer. Instead of the sheep's intestine much trouble may be saved by using German sausage parchment tubing, which can now be purchased, and gives fairly good results.

Experiments.

1. Screw up clip *d* and open clip *c* ; remove the stopper *f*; now, having half-filled the jar *a* with water, work the elastic bottle *b*, when the water will be discharged in jets through the glass tube *e* as soon as it becomes filled. The open end of the glass tube should be raised considerably, and a large trough so arranged beneath it as to collect the water that escapes.

2. The stopper *f* is now to be inserted in the mouth of the tube *e*, and the experiment repeated. 3. Screw up the clip *c*, and replace the tube *v, g, t*, shown in the figure, by the continuous thin tube above referred to, arranging it in the same way under the writing levers (*h*), and bringing the resistance apparatus into the circuit. The writing levers having been accurately adjusted, a small weight also having been suspended by a wide wire loop over each lever where it rests on the tube, the revolving cylinder (*l*), covered with smoked paper, is set in motion. Let an assistant, with a watch placed before him, now compress the elastic bottle (*b*) about once every three seconds for the first minute, once every two seconds for the second minute, and once every second for the third minute. The tracings

on the cylinder having been accurately noted, it is advisable next (4.) to repeat the experiment, after having brought a vibrating reed time recorder in connection with the cylinder, so as to obtain a time tracing below the tracings given by the writing levers. The character and relations of the curves, expressing the passage of the waves along the tube, as well as its rate, should again be carefully noted. 5. Note likewise the variations in the character of the curves on the smoked cylinder when the resistance is increased and diminished—m, n, and o open, m open and n closed, m and n open and o closed, and m and o closed and n open. 6. Compare the tracings obtained upon a quickly revolving with those upon a slowly revolving cylinder. 7. The elastic tube, with the connections, is next brought into the circuit, as in the figure, instead of the continuous tube previously used, and the experiments in Sections 3, 4, and 5 repeated, when some variations in the tracings may be noticed. The heights of the mercurial columns of the manometer (p) are likewise to be carefully observed when the current of fluid is established and the resistance varied. The difference in tension on each side of the resistance will be seen to be markedly different, as also its variations with the discharges of the elastic bag b. 8. While the fluid is circulating open the cocks q and r, and note the character of the issuing streams, and their alteration with an alteration in the resistance. 9. By means of the tube s make connection with a Fick's kymograph; and when the current is established by working the elastic bottle b, tracings can be obtained, and the use of the instrument thus illustrated. 10. Next, by the same means, couple with Ludwig's stromuhr, and this having been filled in the usual way with oil and serum (or water), the experiment is to be made with the help of an assistant, just as if the connection were with the artery of a living animal; and, the current having been established, a calculation made as to its rate—a calculation that can readily be tested by noting the amount of fluid discharged from the tube u by a series of compressions of the elastic bag. 11. Chauveau's dromograph, together with Marey's sphygmoscope, can next be readily introduced into the tube t after s has been disconnected.

Very good results can thus be obtained, which are particularly instructive, and at the same time avoid the necessity of vivisection demonstrations for general class purposes.

12. To show the lymphatic circulation, remove the tube v, and replace it with the tube 1, placing 2 at the same time in the glass jar a. A considerable supply of water should be ready in a large jug, and the experiment is rendered more telling if this water is coloured by the addition of a little logwood or carmine solution. The large bottle 3 should have been previously put in readiness by lifting it from its wooden base 4, inverting it in a hollow stand, and removing the sheet of india-rubber closing the wide orifice in its bottom; then filling it with small moist sponges, taking care to keep the pieces of intestine (5) more or less extended, and not too much compressed.

The coloured water is now poured in from the jug; and, so as to prevent any of it escaping through the tube 6, this should be compressed as soon as the water rises to the open mouths of the central metal tube (7). When the large bottle is full, the india-rubber membrane is to be tightly tied on, and the bottle carefully replaced in its wooden base. By working the elastic bag a current of the coloured water is driven through the thin intestinal tubes ; and when this has been continued for a short time, some of the fluid will pass out through the tubes by exosmose, and very soon the spaces outside will be so filled that the fluid will force its way through the open mouths of the central tube 7, and later through 6 into the little glass reservoir 8; and when the pressure here rises sufficiently, it will pass through 9 into 2. The *vis a tergo* forces the exuded fluid into the reservoir, and the passage of it from here into 2 is effected by the same means, aided slightly by the *vis a fronte* due to the current in 2, in front of the orifice of 9.

As valves are present in 9 and 6, the influence of the negative pressure (as in the thorax) may be demonstrated by occasionally reducing the pressure in the reservoir 8 by means of an air-pump ; and by twisting the tube 6 round the forearm and then contracting the muscles of the latter, the influence of muscular contraction in assisting the onward flow may be demonstrated by the greater amount of fluid that falls into the reservoir 8 when the contractions are frequently repeated.

It is also instructive to make the experiment detailed in the early part of the preceding paragraph without any sponge or coloured water being introduced into the large glass bottle. The gradual oozing of the coloured drops of water through the porous intestinal tubes will readily be seen.

In this last piece of apparatus the large bottle may be taken to represent the body; the sponge as the tissues of the body; the pieces of prepared intestine as the capillaries; and the open-mouthed central tube as the lymphatic vessels, beginning with open mouths in the general lymphatic spaces of the body represented by the spaces in and around the sponges, these being capable of containing so large a volume of fluid, and thus affording a rough indication of the great amount of lymph in which the tissues of the body are, as it were, immersed, constituting, as is known, from one-fourth to one-third its total weight. 8, further, may be regarded as representing a lymph reservoir, and 9 as the thoracic duct opening into the left subclavian vein.

ON SOME POINTS IN THE ANATOMY OF A MEGAPTERA LONGIMANA. By JOHN STRUTHERS, M.D., *Professor of Anatomy in the University of Aberdeen.*

PART III.

THE VERTEBRAL COLUMN.

VERTEBRAL COLUMN.[1]

THE following Table gives the number of vertebræ in each region, with the length of each region and other measurements, in Megaptera, and, for comparison with it, in B. musculus and in B. borealis:—

TABLE I.

	Car-case.	Vertebral Column.			Cervical Region.			Dorsal Region.			Lumbar Region.			Caudal Region.			Leaving for Head.	
	Length in Feet.	No. of Vertebræ.	Feet.	Inches.	No. of Vertebræ.	Feet.	Inches.	No. of Vertebræ.	Feet.	Inches.	No. of Vertebræ.	Feet.	Inches.	No. of Vertebræ.	Feet.	Inches.	Feet.	Inches.
Megaptera,	40	52	28	9½	7	1	7	14	7	½	10	7	2	21	13	...	11	2½
B. musculus,	50	62	37	...	7	1	7	15	8	7	15	11	10	25	15	...	13	...
B. borealis,	36	56	28	...	7	1	5	14	6	2	14	9	6	21	10	11	8	...

[1] In making the following observations on the vertebral column of Megaptera, those of B. musculus and B. borealis were placed beside it for comparison. In this way an appreciation of its distinctive characters could be made. With this view a comparison is given with the corresponding parts in B. musculus, in so

Number of the Vertebræ.—Megaptera has the same number of dorsal vertebræ as B. borealis and one less than B. musculus, but the striking difference is in the lumbar region, Megaptera having only 10, while B. borealis has 14, and B. musculus 15. This gives great shortness to the abdominal region in Megaptera. The caudal region is long compared with that region in B. musculus and in B. borealis in proportion to the total length. The 13 feet of caudal region in Megaptera against 11 feet in B. borealis, while both have 21 caudal vertebræ, is not owing to greater length of the bones in Megaptera but to the great length of the intervertebral fibro-cartilages in Megaptera. The contrast between Megaptera and the other two finners in this respect, seen in dissection, was apparent also in the dorsal and lumbar regions, but was striking in the caudal region. Megaptera is thus characterised by a short "trunk" and a long, robust, and flexible tail, surmounted by a large tail fin. These proportions of the vertebral column are taken from the three articulated columns placed beside each other, the proportions carefully assigned in articulation.

Number of Caudal Vertebræ.—The precise number of the caudal vertebræ must often remain uncertain. In this 50-feet-long B. musculus, what would have come out of the maceration trough as the last vertebra is about 1 inch broad and ½ inch long. But behind it is a conical cartilage, ½ inch long in the now dried condition, and on the upper aspect of this, at its middle, is a rounded bony nucleus only ¼ inch in diameter. What is present at the last caudal vertebra in this Megaptera is a piece of bone about the size of a common nut compressed into a somewhat cubical form (¾ inch broad, ½ inch in height and length, but part of the length is evidently broken off). There may have been a cartilage behind it as in this B. musculus, and still more so in this B. borealis, the last vertebra of which present is 1⅓ inch broad, ⅞ inch long, and ⅝ inch high. There can be absolute certainty only when the very end has

far as comparison is of interest. As this is sufficient to bring out the characters of Megaptera, only occasional references are made to B. borealis. The comparison which I at the same time made between B. musculus and B. borealis was interesting, as bringing out numerous differences between these two species, but this subject I must reserve for some future communication. The parts relating to B. musculus are placed within brackets [ ] for facility of reference.

been carefully dissected, but the circumstances attending the dissection of large whales are generally not very favourable.

Explanation of some of the Measurements in Tables II. and III. (pp. 442–445.) —
No. 1. Vertically from top of spinous process to back part of the body, or, when spine very sloping, to level of under surface of body. In neck to level of lowest part of body.

No. 3. By callipers, from within spinal canal, along middle line of process. From within canal is the only definite point below. In the cervical vertebræ the thickness of the lamina is then deducted, as this had been done in the measurements given in my table of the cervical vertebræ in this *Journal* in 1872, pp. 20, 21.

No. 9. When, as in B. musculus, the measurement would differ according as taken from where the process leaves the fore part or the back part of the body, it is taken from a line drawn between these two points.

No. 13. With callipers, towards the middle of the ends. At the margins it might have been ¼ to ½ inch less.

No. 14. At anterior end, and on the edges of the epiphyses. At the middle would be less reliable, as some have a ridge, some a hollow there. At the epiphysis keeps clear of the chevron tubercles.

No. 15. At anterior end, and on the epiphyses. Just behind the epiphyses might give ¼ to ½ inch more, but the epiphysis is the least variable part, and will form the true end of the consolidated bone.

No. 17. Taken, like No. 16, at the middle. Taken below or above the transverse process according as it is before or behind the transition vertebra; the 7th of Megaptera, the 6th of B. musculus.

No. 18. This measurement may be influenced to the extent of about ½ inch by a superior median ridge, or by the top of the arch being a little more or less pointed.

No. 20. Between upper edges at fore part, being the most prominent part anteriorly. In the neck, where the upper margin becomes the outer, the measurement is between the outer margins of the anterior processes.

No. 21. This measurement, taken with No. 1, shows the contribution made by the chevron bones to the two-edged knife, or "razorback," form of the caudal region in B. musculus, compared with Megaptera.

BODIES OF THE DORSAL AND LUMBAR VERTEBRÆ.

4. LENGTH, BREADTH, AND HEIGHT OF THE BODIES.[1]—On referring to Table II. it will be seen that the largest bodies are those of the first three or four caudal vertebræ. This part is the foundation of the great propelling organ. It is at the junction of about the posterior with the middle thirds of the entire carcase in Megaptera. The greatest breadth (11 inches) is attained by the 2nd and 3rd; the 1st and 4th only ½ inch

[1] The epiphyses of the bodies are still ununited throughout the spine. The ends of the spinous and transverse processes, and the upper margins of the articular processes, all show evidence of unfinished ossification.

TABLE II.—*Measurements of the Vertebræ of Megaptera longimana, given in inches.*

	Atlas	Axis	Cervical, 7.					Dorsal, 14.												
			3	4	5	6	7	1	2	3	4	5	6	7	8	9	10	11	12	13	14

1. Extreme height,
2. " width,
3. Spinous process, length,
4. " " breadth at middle,
5. " " breadth at end,
6. " " thickness at end,
7. " " thickness at middle,
8. " " thickness at middle of end,
9. " " greatest thickness at end,
9. Transverse process, length,
10. " " greatest breadth,
11. " " least breadth (neck),
12. " " thickness at middle,
13. Body, length,
14. " height,
15. " width,
16. Pedicle, breadth at narrowest part,
17. " thickness at middle,
18. Spinal canal, height,
19. " " greatest width,
20. Between anterior articular processes, at front,
21. Extreme height with chevron bones,

TABLE II.—*Measurements of the Vertebræ of Megaptera longimana, given in inches—continued.*

	Lumbar, 10.										Caudal, 21.																				
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Extreme height,																															
2. ,, width,																															
3. Spinous process, length,																															
4. ,, ,, breadth, at middle,																															
5. ,, ,, breadth, at end,																															
6. ,, ,, thickness at middle,																															
7. ,, ,, thickness at middle of end,																															
8. ,, ,, greatest thickness at end,																															
9. Transverse process, length,																															
10. ,, ,, greatest breadth,																															
11. ,, ,, least breadth (neck),																															
12. ,, ,, thickness at middle,																															
13. Body, length,																															
14. ,, height,																															
15. ,, width,																															
16. Pedicle, breadth at narrowest part,																															
17. ,, thickness at middle,																															
18. Spinal canal, height,																															
19.																															
20.																															
21. Extreme height with chevron bones,																															

TABLE III.—*Measurements of the Vertebræ of Balænoptera musculus, given in inches.*

	Atlas	Axis	Cervical, 7. 3	4	5	6	7	Dorsal, 15. 1	3	5	7	9	11	13	15
1. Extreme height,	12½	13¼	10¾	11	11¼	12¾	18¾	14	16¼	19¼	21¼	22¼	22¼	23¾	24
2. Extreme width,	24¾	29¼	27½	26¼	26¼	26	26¼	26¾	25¼	29	32¼	33¼	34¼	35¼	35½
3. Spinous process, length,	…	…	…	…	…	1¾	1¾	8¾	6¾	9	9¾	11¼	11¾	18	18¾
4. ,, ,, breadth at middle,	…	…	…	…	…	…	…	1¼	8	4¾	5¼	6	6	5¼	5¼
5. ,, ,, breadth at end,	…	…	…	…	…	…	…	…	8¾	5¼	6¼	7¾	7¾	7¾	8¾
6. ,, ,, thickness at middle,	…	…	…	…	…	…	…	…	…	…	…	1¾	…	…	…
7. ,, ,, thickness at middle of end,	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
8. ,, ,, greatest thickness at end,	…	…	…	…	…	…	…	…	…	…	…	…	1¾	1	1¾
9. Transverse process, length,	6¾	10¾	9¾	9	9	8¾	8¾	9	9¾	10	11¾	11¼	12	12¾	12¾
10. ,, ,, greatest breadth,	…	…	…	…	…	…	…	1¾	4	5¾	6¾	7¾	7¾	7	6¾
11. ,, ,, least breadth (neck),	…	…	…	…	…	…	1	1¾	2¾	4	2¾	4	4	4¾	4
12. ,, ,, thickness at middle,	1¾	1¾	…	…	…	…	2¾	2	1¾	2¾	1¾	1¾	…	…	…
13. Body, length,	8	2¾	2¾	1¾	2	2¾	7¾	8¾	4¾	6	7	7¾	7¾	7¾	8¾
14. ,, height,	2¾	6¾	7	7¾	7¾	7¾	7¾	7¾	7¾	7	7¾	7¾	7¾	7¾	8
15. ,, width,	…	…	11¾	11¾	11¾	11¾	11¼	11¼	11	10	9¾	10¼	10¾	10¾	10¾
16. Pedicle, breadth at narrowest part,	…	4¾	2¾	2¾	2¾	8¾	8¾	8¾	4	4¾	4¾	4¾	4¾	4¾	4¾
17. ,, thickness at middle,	…	6¾	…	…	…	…	…	1¾	1¾	2¾	1¾	1¾	1¾	1	1¾
18. Spinal canal, height,	6	4¾	8¾	2¾	2¾	2¾	2¾	8¾	8¾	4¾	9¾	10¾	4¾	4	8¾
19. ,, ,, greatest width,	4	6¾	6¾	6¾	7	7	7	7¾	6¾	5¾	4¾	8¾	8¾	8¾	8¾
20. Between anterior articular processes, at front,	…	…	9¾	9¾	9	9¾	9¾	10	9¾	8	4¾	8¾	8¾	8	2¾
21. Extreme height with chevron bones,	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

TABLE III.—*Measurements of the Vertebræ of Balænoptera musculus, given in inches—continued.*

	Lumbar, 15.							Caudal, 25.												
	2	4	6	8	10	12	14	1	3	5	7	9	11	13	15	17	19	21	23	25
1. Extreme height,																				
2. Extreme width,																				
3. Spinous process, length,																				
4. „ „ breadth at middle,																				
5. „ „ breadth at end,																				
6. „ „ thickness at middle,																				
7. „ „ thickness at middle of end,																				
8. „ „ greatest thickness at end,																				
9. Transverse process, length,																				
10. „ „ greatest breadth,																				
11. „ „ least breadth (neck),																				
12. „ „ thickness of middle,																				
13. Body, length,																				
14. „ height,																				
15. „ width,																				
16. Pedicle, breadth at narrowest part,																				
17. „ thickness at middle,																				
18. Spinal canal, height,																				
19. „ „ greatest width,																				
20. Between anterior articular processes, at front,																				
21. Extreme height with chevron bones,																				

less; the greatest height (10¼ inches) by the 2nd, 3rd, 4th, and 5th; the greatest length (8⅝ inches) by the last lumbar and two first caudal, the 3rd and 4th only ⅛ inch less. An eighth of an inch in such measurements may be only incidental. Thus the 2nd caudal has the greatest size in all directions—breadth 11 inches, height 10¼, length 8⅝; and the third and 4th are scarcely less; the 1st only a little less.

From this region the bodies diminish forwards and backwards. In the diminution backwards the height and breadth keep about the same proportion in the first half of the caudal region, and in the last half are more nearly equal. The length remains less than the height or breadth until the fourth last caudal is reached. In the diminution forwards, the decrease in *breadth* is not great—about 1 inch along the lumbar region (10⅝ to 9⅞); along the dorsal region, 1 inch at the 3rd dorsal (9 inches), and at the 1st dorsal ⅝-inch more (to 8⅜-inches), a total diminution of about 2½ inches from the greatest breadth. In *height* the diminution goes on gradually, from the 10¼ inches on the 2nd caudal, to 7 inches at the middle of the dorsal region, and remains at this on to the 1st dorsal, a total diminution of 3¼ inches. In *length* the diminution is great—from the 8⅝ inches of the 10th lumbar, it has fallen to 6⅜ on the last dorsal, and to only 2¾ on the first dorsal. On the posterior half of the dorsal region it is only 1 inch. On the anterior half it is more rapid, from 5⅝ inches to 2¾, being fully one-half. The shortening of the bodies backwards from the great vertebræ is much more rapid than forwards, the length of the 17th and 18th caudal being about equal to that of the 1st dorsal, a distance backwards of 10½ feet (including 15 to 16 vertebræ, from the 2nd caudal), and forwards a distance of 13½ feet (including 23 vertebræ, from the 10th lumbar to the 1st dorsal).

The shortness of the bodies is seen when they lie alongside those of the other finners. The following are the measurements in inches, of the 13th dorsal in the three:—

	Length.	Height.	Breadth.
Megaptera, . . .	6	7¼	9¼
B. musculus, . . .	7	7¾	10¾
B. borealis, . . .	6	5¼	7¼

In Table II. it is seen that, all along the column, the length is considerably less than the height, back to the 17th caudal, where they become about equal.

[In *B. musculus* the largest bodies are those from the 3rd to the 7th caudal, the 5th on the whole the largest. Its height is 10¾ inches, length 10 inches, but the 7th has the greatest breadth, 12½.

The greatest vertebral body in Megaptera is the 2nd of its 21 caudal vertebræ, the 33rd of its 52 vertebræ ; and it has in front of it nearly 17 feet of the vertebral column, behind it, 11½ feet. In B. musculus the greatest body is that of the 5th of its 25 caudal vertebræ, the 42nd of its 62 vertebræ ; and it has in front of it 26 feet of the column, behind it, 10½ feet. In B. musculus the length is as great as the height in the posterior dorsal region (9th to 13th) ; along the lumbar region, less than the height only by ¼ to ½ inch ; in the caudal region the difference may be only slightly greater back to the 11th, where the length becomes less than the height by 1¼ inch, and more backwards, except on the four or five posterior vertebræ where the difference between the height and the length is not great. In Megaptera the length is less than the height on the above-mentioned dorsal vertebræ (9th to 13th) by from 1⅛ to 1½ inch ; along the lumbar region by an average of 1½ inch, in contrast with the ¼ to ½ inch in B. musculus. In *B. borealis* the length is even greater than the height, from the 9th dorsal back to the 7th caudal.]

5. THE EPIPHYSES.—The lengths of body given include the epiphyses. On the 2nd or 3rd caudal the epiphyses, at midway between the transverse process and the pedicle, are ½ inch thick. [On the corresponding and neighbouring vertebræ of the B. musculus, the epiphyses are 1 inch thick; in the B. borealis they are ½ inch thick.] In front of the last two lumbar, the thickness has diminished to ⅜ inch; at the first dorsal, to about ⅔. Backwards, along the caudal region, the epiphyses remain undiminished in thickness to the 10th, after which the bevelling of the edges, especially of the posterior epiphysis, renders it not easy to measure the thickness, but back even to the 17th caudal, the anterior epiphysis is still ½ inch thick. After the 10th caudal, the posterior epiphysis is somewhat thinner than the anterior. After the 10th, the back of the bodies becomes convex, the front remaining more nearly flat. This is due to the bevelling off of the hinder edge of the posterior epiphysis in the rapid tapering of the hinder vertebræ of the tail. These measurements are taken at the unfinished abrupt edges of the epiphyses, but 1 inch to 1½ further in,

where the annular platform is most raised, the thickness of the
epiphyses is greater. This is well seen when the epiphysis
happens to be broken. The posterior epiphysis of the 2nd
lumbar, ⅜ inch at the edge, is ⅝ inch at 1¼ inch in from the
edge. The anterior epiphysis of the 11th caudal, scarcely ½ inch
at the abrupt edge, is almost 1 inch further in. On the 15th,
16th, and 17th caudal, which admit here of being measured
throughout, the anterior epiphysis is ⅛ inch thicker than the
posterior of the same vertebra, and is not thicker internally than
at the edge. From the 12th to the 17th caudal, the bodies can
be exposed and are seen to be convex on both aspects where
covered by the epiphyses, rendering the deep surface of both
epiphyses cupped. The length of the bodies was measured from
the annular elevation, giving the greatest length.

6. FORM OF THE BODIES—*Markings on the Ends.*—Megaptera
differs from B. musculus in the appearances presented by the
ends of the bodies. In Megaptera the streaked annular plat-
form for the capsular part of the intervertebral disc is broader
in proportion to the enclosed pulp-area, is more raised, and has
its lines more pronounced than in B. musculus. There is a
groove between them in Megaptera owing to the elevation of
the capsular ring especially at its inner part, while in B. mus-
culus the central area stands out more abruptly owing to the
flatness of the ring. The greater relative breadth of the ring
in Megaptera is seen throughout the spine, and increases back-
wards. At the 6th lumbar vertebra, the proportions of the
ring to the pulp-area are, in Megaptera, 1¾ and 6½ inches; in
B. musculus, 1½ and 7½ inches; at the 6th caudal, in Megaptera,
2½ and 5½ inches; in B. musculus, 1¾ and 7¾ inches. [In B.
musculus the ring is flat, becoming a little convex in the caudal
region. B. borealis in these respects resembles B. musculus in
contrast with Megaptera.]

Form of the Ends.—The ends of the bodies in front of the
caudal region are flat. They may undulate a little from the
slight projections at the pedicles and transverse processes, and
appear slightly convex from the falling away external to the
elevated part of the capsular platform, but on the whole the
end is flat. After the 1st caudal, one on both ends become
convex. From the 2nd to the 8th the convexity is not great

and is about equal on both ends. The 9th and still more the 10th, have the posterior end more convex than the anterior; the 11th, the first post-chevron vertebra, very much so. The 12th and 13th, more especially the 13th, become decidedly bi-convex, the posterior surface still the most convex, their curvatures much resembling those of the human crystalline lens. The concavity is not due merely to bevelling but is seen over the central pulp-area also. Behind these two the plano-convex form is resumed, the anterior end nearly flat, the convexity of the posterior end less than that of the biconvex vertebræ. The two biconvex bodies are those which follow, with one transition vertebra between, after a complete neural arch and chevron bones have ceased. This form of the bodies must give great freedom of motion to this part.

The caudal vertebræ, from and after the 14th, instead of having the sides convex both ways, like the three just in front, are pinched at the middle, rendering the sides concave vertically at the middle. This gives a four-cornered shape, in antero-posterior view, to these vertebræ, in striking contrast to the circular form of the vertebræ in front of them.

[In *B. musculus* the vertebræ continue flat-ended back to the 15th caudal (the first after the disappearance of a complete neural arch), the posterior end of which is somewhat convex. This increases on the 16th, and the plano-convex form is continued on the vertebræ behind, but there are no bi-convex vertebræ in this B. musculus. The four-cornered form begins on the 18th caudal, but is not very well marked till the 20th. The pinching at the sides is rather in the form of an obliquely upward and backward fossa than that of the vertical concavity of the middle of the side presented by Megaptera. In *B. borealis* the 12th and 13th caudal, and to a less extent the 14th, are bi-convex.]

Superior and Inferior Median Ridges of the Bodies.— The sharp *superior median ridge* seen on the bodies of the cervical vertebræ flattens down on the anterior dorsal into a low broad median convexity. Increasing as we go back, this elevation at the 5th dorsal has assumed a definite form 2 inches in breadth with a definite oval foramen, it may be more than one foramen, on each side of it. At the beginning of the lumbar region it is more raised and narrowed to 1½ inch, and bounded by a more elongated entrance to the foramen. From the 7th to the 10th lumbar the

ridge rises abruptly, like a finger laid along the middle of the body, the foramina in some (7th and 10th) communicating freely below it. This longitudinal bridge on the 8th, now broken, has been constricted, or even wanting at the middle. On the first five caudal it stands up as a triangular ridge, with the depression and foramen, or foramina, at each side, narrowing backwards to the 5th, where it is a sharp well-marked ridge. On the 4th caudal it has again been undermined, so as to form a bridge, so narrow that it has given way. On the 6th caudal, and on the four succeeding vertebræ, those with neural arch complete, it has entirely disappeared, the floor of the canal being smoothly concave from side to side. After an interval of four vertebræ (11th to 14th), which have a large median foramen, the median ridge reappears, on the 15th and succeeding vertebræ, with a foramen or two on each side of it.

This ridge must belong, as I found in the neck of *B. musculus*, to the superior common ligament of the bodies. The 6th caudal, on which it ceases as a ridge within the canal, is the last vertebra with a pronounced transverse process.

[This pronounced superior median ridge is a character of Megaptera, as compared with B. musculus and B. borealis. In *B. musculus*, it is seen in the neck, and very faintly on the two or three anterior dorsal, not at all on the other dorsal, and very faintly on the lumbar and anterior caudal; in the posterior part of the lumbar region as a broad low convexity, but not at all projecting as in Megaptera. In *B. borealis* this ridge is even more completely absent, faintly perceptible to the finger in the posterior lumbar region only.]

Inferior Median Ridge.—This sub-vertebral median ridge, seen especially in the *lumbar region* of Cetacea, is strongly marked both in depth and breadth about the middle of the lumbar region in Megaptera. Beginning on the 1st lumbar it is there broad and long; on the 2nd it is sharp, but still has the deeply concave outline. From the 3rd to the 8th this crest projects so much as to give the body, on side view, a convex outline below, strongly marked on the 5th and 6th. On the 9th and 10th it is well marked, but the outline is again a little concave. Viewed from below, the crest is seen on the 4th lumbar to broaden out posteriorly; on the 5th, its posterior ¾ form a wide triangular surface, 2 inches broad behind; on the 6th, the whole ridge is broad, ¾ inch at the middle,

expanding at both ends. On the next four again it is a sharp ridge, broadening out on the posterior $\frac{1}{4}$ or $\frac{1}{3}$ into a triangular surface, more marked as we go back, but on the 10th it shows no tendency to the bifurcation presented by the 1st caudal for its chevron bone.

The subvertebral ridge shows itself on the *dorsal region* from the 5th to the 12th. The first five dorsal bodies are, on side view, rather convex below, the 4th decidedly so, but, unlike the cervical, have no distinct median ridge. Behind the 5th they are a little concave below, notwithstanding the crest, except the 7th and 9th, which are nearly level below. Seen from below, this ridge on the dorsal vertebræ is broad on the more anterior, narrow on the more posterior, of these vertebræ.

[In *B. musculus* the subvertebral ridge is present, but low and blunt on the five anterior dorsal; reappears better marked on and after the 13th dorsal; is more decided on the 2nd lumbar, and, after the 2nd, throughout the lumbar region is projecting enough to fill up the concavity of the bodies. Seen from below, the ridges are not flattened out except at their extreme ends.]

7. COSTAL MARKS.—The bodies of the 7th cervical and 1st and 2nd dorsal vertebræ present tubercles on their hinder part. That on the 7th cervical is serial with the inferior transverse processes, those on the 1st and 2nd dorsal are respectively 1 inch and 1$\frac{1}{2}$ to 2 inches higher up. They are elongated vertically, their upper ends at about the middle of the body. The posterior slope presents an unfinished surface, as if formerly cartilage-covered, is convex both ways; in size, about 2 to 2$\frac{1}{2}$ inches vertically, $\frac{3}{4}$ to 1 inch in breadth; that on the 1st is the broader, that on the 2nd the longer vertically; that on the 7th cervical is a little smaller than the one on the 1st dorsal. The 3rd dorsal, on the corresponding part of the body, has a narrow crescentic mark about $\frac{1}{2}$ inch broad, as if costal; best marked on the left side. Each of these costal marks is about on a plane with the end of the transverse process of the vertebra behind. As the ribs fall short of reaching the bodies, these marks can have attached only the ligament prolonged from the rib to the body of the vertebra in front.

[In *B. musculus*, costal tubercles exist on the 7th cervical and 1st, 2nd, and 3rd dorsal bodies. They are less elevated, and their surfaces

of attachment look more outwards than in Megaptera. The transverse processes here are directed so much forwards, that a ligament passing from near the costo-transverse articulation to the costal tubercle of the vertebra in front would be directed obliquely backwards.]

BODIES OF THE CAUDAL VERTEBRÆ.

8. HÆMAL TUBERCLES, RIDGES, AND GROOVE.—The subvertebral ridge, single and sharp on the 10th lumbar,[1] bifurcates on the 1st caudal. Along the front half of the body of this, the *first caudal*, vertebra there is a shallow groove, bounded by low ridges about 1 inch apart; then the nutritious foramina; and then, along the posterior third of the body, the hæmal tubercles rise rapidly, the space between them ½ inch deep and 1¼ inch wide. These tubercles are convex and blunt below, rather than bevelled behind, for the support of the 1st chevron bone. From the 2nd to the 6th the *posterior hæmal tubercles* are larger than those of the 1st, attaining their maximum on the 3rd. They are bluntly triangular on side view. Their anterior border, continuous with the edges of the hæmal groove, is smooth. Their posterior slope presents a flat triangular surface, about 2 inches broad at the summit, against which the anterior slope of the chevron bone rests. Their summits are about 3 inches apart, the triangular space between them 1 to 1½ inch deep. On the anterior half of these bodies (2nd to the 6th) the hæmal groove is bounded by sharp edges.

The *anterior hæmal tubercle*, smaller than the posterior, increases gradually from the 2nd to the 6th, diminishing gradually the interval between the anterior and posterior tubercles. This interval becomes a mere notch on the 6th by the curving forwards of the posterior tubercle. This notch, half-oval in shape and about two fingers'-breadth, is converted on the 7th vertebra into a foramen by the meeting of the posterior and anterior tubercles. The now-constituted *hæmal ridge* is perforated laterally on the 8th as well as on the 7th, forming the first stage of the vertical passage in these two vertebræ. On

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[1] Rudolphi, *loc. cit.*, speaks of and figures eleven lumbar vertebræ; Van Beneden and Gervais, *loc. cit.*, speak of "neuf lombaires et vingt-deux caudales," but figure the lumbar as ten (pls. x. and xi.). It is evident that the vertebra which I assign as the 1st caudal is really so, and therefore that ten is the correct number of the lumbar vertebræ.

the 8th vertebra, and back to four or five from the end, there is a continuous hæmal ridge, most projecting at the middle, giving the vertebra, on side view, a convex outline below.

After the 1st caudal, the *hæmal groove, or fossa*, is concave longitudinally as well as transversely, owing to the rise of the tubercles. In width it increases from 2 to 2½ inches at the middle, where it is widest, and is about ½ inch in depth. Here two nutritious foramina pierce the bone, about goose-quill size, one on each side, ¾ to 1 inch apart. On the 7th the hæmal groove is in length 4 inches; in breadth, in front 3 inches, posteriorly 2 inches; in depth 1½ inches. It now assumes a more oval form, and on the 10th (the last chevron vertebra) it is in length 4 inches, in breadth 2¼, in depth 1½; the nutritious foramina close together; the openings of the vertical passages, in the roof, about 1 inch apart. On the 11th, the long axis of the oval is still antero-posterior, 2 to 2½ inches long, 1¾ broad, and ¾ inch deep. The septum between the mouths of the vertical passages is contracted to ⅜ inch. Behind the 11th, the hæmal fossa becomes oval transversely, and the two great apertures become gradually more separated. On the 12th, the fossa is broader than long, the great apertures ⅝ inch apart. On the 14th, the length of the fossa is 2 inches, the breadth 2½ inches, the distance between the two great apertures 1¼ inch. After the 15th, the fossa becomes broadly diamond-shaped. After the 14th, the distance between the apertures of the vertical passages diminishes actually, but not in proportion to the lessened size of the bones. At the 18th vertebra they are still ¾ inch apart, the fossa 2 inches broad, the length ½ inch less. After the 11th, the two nutritious foramina are transferred from between the great apertures to behind them, and continue so after the septum between the great apertures has regained breadth.

9. VERTICAL PASSAGE AND FORAMINA.—This large passage, present in the middle and posterior caudal regions establishes, when complete, a communication between the hæmal and neural canals. In some of the posterior caudal vertebræ it is a simple vertical canal; in front, as in the 7th caudal (the 12th or 13th of B. musculus, the 9th of B. borealis), it occurs as a series of three perforations (4 foramina) in the vertebra, on each side. On its way from the hæmal to the neural canal three stages

may be recognised—the lower stage, piercing the hæmal ridge;
the middle stage, piercing the body internal to the transverse
process, showing lower and upper foramen; and the upper stage,
piercing the neural arch. The study of the changing position
of these great apertures in the transition from the three-per-
foration condition to the simple condition behind, is the more
interesting as they form characters by which these vertebræ of
Megaptera may be distinguished from those of B. musculus and
B. borealis. These are great apertures, all large enough to
admit the point of a finger. They diminish upwards. While
within the bone, the passage communicates laterally with the
exterior by a system of apertures seen on the side of the bodies.

The *lower stage* exists only on the 7th and 8th, as the per-
foration in the hæmal ridge, large enough to admit a large
finger. Behind the 8th, the passages pierce the roof of the
hæmal groove, and become at once concealed in the bone.

The *middle or lateral stage* of the vertical passage exists
from the 6th caudal vertebra backwards. On the *fifth*, it has
run out into the deep notch bounding the transverse process
anteriorly. The deepest part of this notch, on the right side, is
marked by traces of the passage, and a wide groove passes up
from the notch on both sides. On the *sixth*, it is a canal,
1½ inch in length, in the side of the body, 1 to 1½ inch internal
to the transverse process. Between the notch and the foramen
there is an interval, 2 inches on the right side, ¾ inch less on
the left side, and the notch is to the extent of that difference
deeper on the left than on the right side. The sixth is the last
vertebra with a projecting transverse process. On the *seventh*
this stage of the passage is 4 inches in length within the bone,
the lower aperture half-way below, the upper aperture less than
half-way above the transverse process. From the upper aper-
tures of the 6th and 7th, broad, well-marked grooves are seen
to pass up to the neural perforation or notch. These grooves
appear to have had a membranous roofing, at least at their
lower part. On the *eighth*, the middle stage is now roofed over
along nearly the whole side of the body, beginning to be so
immediately after the perforation of the hæmal ridge, leaving
only a large window between, and reaching up to within 1 inch
from the neural perforation. *Behind the eighth*, the passage

enters the bone directly from the hæmal groove, and its upper opening is at first high on the side of the bone; then, after the complete neural arch ceases (on the 11th), on what may be termed the upper aspect of the bone; but it is not till the 14th or 15th, with the change to the square form of the body, that the opening is fairly on the top. On the *eight posterior* vertebræ (14th and backwards) it is simply a large, nearly vertical, rounded canal on each side of the flat-sided bodies, through which one may see, and is essentially the same on the three preceding (11th, 12th, and 13th) vertebræ, but their widening body gives the passage a curve outwards. These *eleven posterior* are the vertebræ behind the chevron bones, and those which want a complete neural canal. The lower aperture of the passage is larger than the upper. The latter apertures are wider apart than the lower. The following are the distances between the upper apertures in inches:—On 18th caudal, 1 inch apart; 14th, 1¾; 12th, 3; 11th, 3¼; 10th, 3½; 8th, 4¼; 7th, 7¼; on 6th caudal, 7¾ inches apart.

The *upper stage* is present from the 7th back to the 14th. On the first four (7th to 10th), piercing to a completed neural canal; on the second four (11th to 14th), piercing below the low broad ridge which represents a commencing pedicle, to reach the groove or pit which represents the floor of a neural canal. (It is a groove and pit on the 11th, a mere pit on the 12th, 13th, and 14th.) On the second four, the neural perforation does not, as on the first four, open separately on the exterior, but goes in as a narrow passage from the middle stage near the wide upper aperture of the latter. The perforation representing the upper stage is either on one side only, or is not symmetrical. It occurs only on the right side in the 7th, 9th, and 12th; only on the left side in the 8th, 10th and 11th, 13th and 14th. The 7th shows on the left side a groove in the deep notch behind the pedicle, ascending from the second stage of the passage, but not so far forward as the perforation on the right side. On the 6th, the perforation has ceased on both sides, but the notches are not symmetrical, the right being more anterior than the left. Behind the 7th, the perforation is at the middle of the broad neural arch, and on the side on which there is no perforation there is no notch or

roundabout groove. On the seven posterior (behind the 14th) the neural perforation ceases. A median septum rises to the level of the edges of the vertebra, separating the funnel-like fossæ into which the passages open, and on each side of the septum nutritious foramina are seen, crow-quill to goose-quill size. In the four previous vertebræ (11th, 12th, 13th, 14th) these nutritious foramina are gathered together into a larger central one in the groove or pit which represents the opened-out neural canal.[1]

Meaning of the Vertical Passage and of its various Conditions.—In endeavouring to find an explanation of the different arrangement of the vertical passage and its foramina along the region, it is observed that the passage is within the body of the vertebra, where there are no transverse processes. Also that, with this roofing-over of the passage, the side of the body is nearly filled up, or (as on the 11th, 12th, and 13th) even convex ; and that the excavation of the side of the vertebral body begins on the 7th and 6th, as we go forward. If the hinder vertebræ, are taken as the type, with the passage concealed in the bone, the commencing excavation on the 7th and 6th would explain the unroofing of the upper and lower parts of the middle stage on these vertebræ and the entire opening up of it on the 5th. Or, going backwards, we perceive that, on the anterior four caudal vertebræ, the segmental blood-vessels do not mark the bone at all, that they begin to groove the bone on the 5th, to pierce it gradually on the 6th and 7th, with disappearing transverse processes, and, after the 7th, to become covered by a bony roof. The adaptation may thus be

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[1] *Size of the Foramina of the Vertical Passage.*—The size of the apertures of he second stage does not go in proportion to that of the vertebræ. They receive the point of the fore-finger, oval antero-posteriorly, with almost no diminution back to the 10th. The next three are encroached on a little by the broad low pedicles. In the 14th and 15th they have become round and receive the ring-finger above (diameter $\frac{7}{12}$ inch), the fore-finger below. In the 16th they are large enough above to receive the point of the little finger. In the 17th and backwards they are oval transversely. They are always wider below than above. The perforation of the hæmal ridge of the 7th admits the thumb, of the 6th the fore-finger. The perforation of the neural arch of the 7th admits the point of the fore-finger ; of the 8th and 9th, the point of the little finger ; of the succeeding vertebræ (10th to 14th) less. These are present on one side only, as above noted, but the neighbouring aperture of the second stage is not larger on the side which possesses a neural perforation than on the side which does not.

in affording protection from pressure after transverse processes cease, or protection in the narrow part of the tail. The levelling up, or convexity, of the caudal bodies might thus be regarded as the result of the passages requiring to be roofed over; or the roofing-over may be owing simply to the form of the bodies in adaptation to some other function. The perforation of some of the transverse processes farther forwards in B. musculus and B. borealis is explained by the interruption offered by the great breadth of these processes in them as compared with Megaptera.

10. LATERAL FORAMINA ON THE BODIES OF THE CAUDAL VERTEBRÆ.—Besides the usual nutritious foramina—ranged especially towards the fore and back parts of the bodies, the former directed forwards, the latter backwards, here mostly the size of a crow-quill or less,—there is on the caudal bodies a system of larger foramina by which the roofed-over parts of the vertical passage send communications laterally to the surface. Three series may be recognised. They are best understood by beginning behind.

Only the *middle series* are present on the hindmost eleven bodies; on the hindmost eight, as a single aperture at the middle of the side, where the body is constricted, going straight into the vertical passage; on the next three (13th, 12th, 11th caudal) as a pair, arranged antero-posteriorly, the communication having bifurcated as the bodies increased in length and outwardly. This series is continued along the chevron vertebræ, close below the line of the transverse processes, on to the 7th. The upper and lower series exist only on the 8th, 9th, and 10th (the three posterior chevron vertebræ). The *upper series*, above the transverse processes, the smallest, occur also as a pair, but are less regular or symmetrical than the middle series. The *lower series*, the largest, three, two, or one in number, pierce the hæmal ridges. That of the 8th is so large that it might be mistaken for the passage, but the passage is continued up inside the bone immediately after perforating the hæmal ridge. The upper and lower series have disappeared on the 7th vertebra from the unroofing of the passage. On the 6th vertebra all the lateral foramina are rendered unnecessary from the shortness of the passage.

Looking to the *direction* of these lateral openings, their general tendency is seen to be downwards, the sharp boundary above, the grooved side below. This is plainly seen in the lower series and on the middle series where they are single. When they become double, in the chevron region, the posterior foramen is directed also backwards, the anterior one forwards. The forward and backward direction is more marked on the upper series. On some a shallow groove is seen to pass between the middle and the upper series. The position of the sharp and the grooved sides of the great foramina of the vertical passage accord with the upward course of the passage.

[*Vertical Passage and Foramina in B. musculus.*—The position of these foramina would be sufficient to distinguish B. musculus from Megaptera. The *lower stage* of the passage is present on the 11th caudal vertebra as a half-oval notch in the hæmal ridge; on the 12th, 13th, and 14th as a foramen. The *middle stage* is present as a foramen in the transverse process from the 7th to the 13th, the three anterior of these in the process proper, the three posterior between the process and the side of the body. In the 7th the foramen is large, 1⅔ by 1⅔ inch; the bar of bone in front of it 1 inch broad. In the 6th, there is a deep notch in the front of the transverse process instead of a foramen. On the 14th, the middle stage opens high on the body, and behind the 14th it opens at the top. The *upper stage* on the 12th and 13th is present as a notch; on the 14th (the last complete neural arch) as a foramen on the right side, as a notch on the left; on the 15th and 16th, as a foramen on both sides; on the 17th to the 20th, as an open fissure crossing the middle line between the upper apertures of the second stage; on the 21st, 22nd, and 23rd, a septum intercepts this fissure in the middle line.

The great breadth of the transverse processes in B. musculus accounts for their being perforated so far forwards as on seven vertebræ anterior to the first one (the 14th) in which the second stage of the passage is roofed over. The apertures of the passage (judging by the upper apertures of the second stage) are of about the same size and form as in Megaptera, except those in the 8th, 7th, and 6th transverse processes which are larger, the 7th admitting the forefinger, the 6th admitting three fingers.]

(*To be continued.*)

DEVELOPMENT AND TRANSITION OF THE TESTIS, NORMAL AND ABNORMAL. By C. B. LOCKWOOD, F.R.C.S., *Hunterian Professor, Royal College of Surgeons, England.* (PLATE XVII.)

LECTURE III.

Oviducts.

BEFORE proceeding with the transition of the testicles, the history of the oviducts, or, as they are usually called, the Müllerian ducts, may be briefly mentioned. Before referring to the development of these canals in rabbits' embryos (the type which has been mainly used in these investigations) it is convenient to describe their appearances in certain pigs' embryos, whose Wolffian bodies and ducts were exceedingly large, and in which the characters of the oviducts could be ascertained with some degree of certainty. These embryos, after hardening, were 1·8 c. long, and had fore and hind limbs of same length, but devoid of flexures or digits, and with the faintest trace of cartilage in their interior. The permanent kidneys had just developed, and the Wolffian bodies were exceedingly large, being 6 mm. long, and nearly at the period of their greatest development; dorsalwards they were suspended in the pleuro-peritoneal sac by a broad mesentery; whilst ventralwards, along their middle third, the genital mass was united to them by a slightly constricted neck; the genital mass was in the indifferent stage, and afforded no indication of its ultimate fate. The Wolffian ducts were exceedingly capacious, and lined throughout with a single layer of very short cubical epithelium. But, although the capacity of these ducts was so great, they caused no prominence upon the surface of the Wolffian body, except towards its hindermost end; there they gradually separated off and ran, in the midst of a cord of mesoblast, to empty into the urogenital sinus.

The portions of the oviducts which had developed were A, their abdominal openings, and B, a short length of their epithelial lining. The abdominal opening (fig. 42) was situated towards the inner and ventral aspect of the Wolffian body and a short distance (twenty thin sections) from its foremost end; it was lined with short columnar epithelium, continuous with that which clothed the Wolffian body and lined the rest of the pleuro-peritoneal sac; however, it is to be noticed that its cells were both larger and longer than those of the peritoneum. The inner and outer boundaries of the ostium were formed by two jutting processes, and the recess behind the outermost was continuous with the lumen of the oviduct. This continuity was effected very simply by the epithelial recesses becoming deeper, and extending further outwards, until, at last (fig. 43) it became a distinct canal, lying between the Wolffian duct and the peritoneal epithelium. Followed tailwards, this canal speedily lost its lumen (fig. 44), and ended in a solid column of cells, which was wedged in between the Wolffian duct and the peritoneal epithelium. The ostium of the oviduct is situated immediately in front of the foremost end of the genital mass (fig. 44), whilst its hinder impervious extremity reaches but a short distance tailwards. Thus, although the oviduct is still exceedingly rudimentary, it already affords evidence of its final disposition; for, whilst its ostium is in front of the genital mass, its canal courses round its outer margin to accompany, at last, the Wolffian duct.

This specimen enables us to infer that, in some respects, the oviduct resembles the Wolffian duct. For instance, it is obvious that its foremost end develops sooner than its hinder part, and that the latter is at its first development like the Wolffian duct, in that it consists of a solid column of cells. However, the specimen affords no definite information as to the origin of the oviduct. Although the Wolffian and Müllerian ducts are so near to one another, yet the epithelium of the oviduct is so unlike that of the Wolffian duct, and so distinct from it, that it seems unlikely that it originated thence. On the other hand, there is no doubt whatever that the epithelium of the oviduct is continuous with the epithelium of the surface of the Wolffian body, and the weight of evidence seems in

favour of the view of Egli, Kölliker, and Janošik, that that is its source in the Mammalia. The researches of Balfour and Sedgwick, which were referred to in the first lecture, tend to show that in Aves the ostium of the oviduct is formed from the hinder groove of the pronephros. Therefore, before leaving this pig's embryo, we might endeavour to ascertain whether it affords any information upon that point. Although I am unable to adduce any evidence of the actual existence of a pronephros in the pig, nevertheless, assuming that that organ had been present, it would be improbable for it to have helped in the formation of the oviduct, because the foremost part of that canal is some distance from the situation which the pronephros might be supposed to have occupied had it ever existed, being situated at least twenty sections beyond the foremost end of the mesonephros; this is borne out by longitudinal sections made from other members of the same litter.

The Wolffian body and its duct, and the rudiments of the oviduct, were so large and easy to observe in these pigs' embryos that I regret to have been unable to obtain similar material for investigating the earlier stages. In rabbits' embryos the early stage of the oviduct seems hard to observe; but the specimens in my possession bear out the statement made in the first lecture, to the effect that the structures which had been supposed to represent the pronephros entirely disappear, and therefore take no part in the formation of the oviduct. In other respects they countenance the view that the oviduct begins by an ingrowth of the epithelium of the urogenital ridge, and, finally, they fully bear out Kölliker's observations upon its later stages.[1]

Genital Cord.

Although in the male the oviduct is functionless, and only represented by some interesting remains, nevertheless this circumstance has no particular influence upon the early stage of its development. This is exemplified by a human embryo which was mentioned in a previous lecture (Lect. II. p. 41), and which was ⅝ths of an inch long, and estimated to have arrived at about the seventh week of intrauterine life. In this specimen the

[1] *Entwickelungsgeschichte*, p. 977.

genital mass was in the indifferent stage, and towards its upper end[1] there were several villous projections, the commencement, presumably, of the fimbriæ of the oviduct, or, as later it is called, the Fallopian tube. The oviduct itself skirts round the outer margin of the genital mass, and after gradually approaching the Wolffian duct runs in company with that canal towards the lower end of the Wolffian body, where they together enter a thick mesoblastic cord, which is seen in a previous drawing (fig. 39, p. 61, Lect. II.). At this period, the seventh week, the cord which contains the Wolffian and Müllerian ducts is very short, and runs gradually inwards to unite with its fellow of the opposite side, and fuse with the mesoblast in which the urinary bladder is embedded. It is convenient to assign their names to these cords, and they should be called respectively the right and left genital cords and the common genital cord. As is well known, after the oviducts have entered the common genital cord they coalesce into a single canal, which ends in the urogenital sinus; the Wolffian ducts, on the other hand, remain apart, and open separately into the same space. In fœtuses at full term it is usual to find the rudimentary oviduct, with a fimbriated end, lying in the digital fossa close to the globus major (v., fig. 45); this structure sometimes possesses a distinct canal. In the specimen which has been figured there are also two large spatulate and pedunculated bodies attached to the globus major; there is usually but one of these bodies, and their meaning seems still very obscure.[2]

Transition of the Ovary or Testis.

Method of Investigation.—Apparently the reproductive organs of the seven weeks' human embryo which has just been referred to have, with reference to the other viscera, begun to occupy a lower position in the abdomen, or, in other words, the transition of the ovary or testis, whichever it may be about to become, has commenced.

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[1] So far specimens have been described as though the venter of the embryo was towards the ground. In this lecture the terms ordinarily adopted in human anatomy will be used, and the relations of structures spoken of as though the body was erect.

[2] Wertheimer, art. "Testicule," *Dic. Encyclopédique des Sciences Médicales,* p. 533.

The transition of the ovary and testicle has been mainly studied by dissection, and, perhaps, there is not much left to be ascertained by that method. For the earliest stages, however, it is desirable to use properly prepared series of histological sections, and since, as yet, this method has been but little used, I propose in that which follows to give the main facts learnt by its employment. By the paraffin method consecutive sections can be obtained in which the relations of the various organs to one another, and to the skeleton, can be studied without fear of disturbance. As the supply of reliable human embryos is necessarily limited, some of the earlier stages will, as a preliminary, be studied by means of rabbits' embryos.

The transition of the reproductive gland has two stages; the first comprises alterations in its position within the abdominal cavity; the second its passage through the abdominal wall into the scrotum.

Before discussing these two phases, it is desirable to endeavour to determine upon what evidence movements of the ovary or testis may be judged to have taken place. It will be readily agreed that the relations of the gland to the skeleton, more particularly to the pelvis, are likely to yield the safest information upon this question. Therefore, for the present, I propose to consider the matter from this standpoint.

Earliest Relations of the Reproductive and Urinary Organs of the Rabbit to each other and to the Skeleton.

It is customary for authors to describe the position of the genital mass and Wolffian body with special reference to their relation to the kidney. This is calculated, I believe, to lead to erroneous conclusions, unless particular care is taken to observe their mutual relations to the skeleton. When, during the thirteenth day, the permanent kidneys of the rabbit appear, they are situated, as we have seen (Lecture II. p. 54, fig. 29, Pl. II.), behind the lower end of the Wolffian body and a little lower in the abdomen than the genital eminence. However, on the fourteenth day, the permanent kidneys have grown forwards (fig. 30, Pl. II.) until they lie behind the middle third of the Wolffian body, and consequently opposite the genital

mass. This marks the point from which observers consider the transition of the testis or ovary begins. However, it is clearly wrong to speak of the testicle developing in front of the kidney, for the contrary is the case; and, as we have seen, the kidney develops after the Wolffian body and genital mass, and behind *them.* In these rabbits' embryos it would be wrong, so far, to say that the genital mass and Wolffian body had begun to migrate, although, judging from their relations to the kidney, and assuming that the latter were immobile, it would be easy to imagine that movement had occurred. Another circumstance which might strengthen that impression is, that whilst the kidneys are developing, the lower end of the Wolffian body grows, as may be seen in the figure of the Wolffian body already described (fig. 39, Lect. II. p. 61), and tends towards the lower part of the abdomen. In consequence of this growth the Wolffian body appears lower in the abdomen, both as regards the kidney and as regards the skeleton. This point will be clearer as we proceed with the description of the transition in human embryos.

Thus, in the rabbit, the earliest changes in the mutual relations of the reproductive organs and kidneys are mainly due to growth and development in the organs themselves. The next step is to consider the early relations of the kidneys and reproductive organs to the cartilaginous skeleton.

Since the lower part of the vertebral column and pelvis are the portions of the skeleton with which the reproductive organs and kidneys are principally in relation, we will proceed with their early development. The Wolffian body and genital mass have attained considerable dimensions prior to the appearance of the cartilaginous vertebræ. For instance, in the embryo of thirteen and a half days, whose Wolffian body and genital mass was described in the second lecture (Lect. II. p. 46, fig. 37), the cartilaginous bodies of the vertebræ could just be discerned. There was, however, no trace of the pelvic cartilages, and the hind limb consisted of nothing but mesoblast, blood-vessels, and nerves, together with a covering of epiblast. In this embryo the ureter had appeared, and ended in an irregular dilation a few sections nearer the tail than the hinder end of the Wolffian body.

The pelvic cartilages appear towards the end of the thirteenth

day close to the tail end of the Wolffian body. They originate in a quantity of mesoblast which there is in that region, and an idea of the position of this mesoblast in the human embryo may be gathered from the drawing of a very early specimen given in the first lecture (vol. xxi. fig. 1, p. 637). The acetabular portion of the pelvis develops first, and the iliac cartilages extend from it behind the Wolffian body and towards the kidney. By the middle of the fourteenth day the iliac cartilage reaches well behind the Wolffian body; and the lower part of that organ is quite close to the lower part of the abdomen, and about opposite the head of the femur. Thus the Wolffian body of the rabbit acquires relations with the ventral surface of the pelvis, owing to the manner in which that part of the skeleton is developed, and not on account of any active movements which it (i.e., the Wolffian body) may be supposed to have undergone. Moreover, after the growth of the iliac cartilages the position of these organs seems, by contrast, lower in the abdomen; though, without doubt, the growth of the so-called urinary part of the Wolffian body conduces to this impression.

The influence of these processes of growth upon the apparent position of the genital mass may, perhaps, have been inferred. The first trace of the kidney develops behind the Wolffian body, opposite the lower end of the genital mass; the organ speedily grows, and by the fourteenth day reaches as far as the level of the upper end of the genital mass. At this stage I propose to leave this question, to be resumed by means of human embryos suitable for the investigation of the subsequent stages.

It is hard to ascertain the exact relation of the kidneys and reproductive organs to the spine, because no single longitudinal section divides sufficient of each to these organs to permit of a correct estimate. The most that can be safely affirmed is, that both kidney and genital mass lie opposite the lumbar spine, whilst the Wolffian body extends a little beyond above, and a great deal beyond below.

The acetabular portion of the pelvis develops almost opposite the lowest end of the Wolffian body, and therefore at some distance from either the kidney or genital mass; and although . the iliac cartilage grows upwards behind the lower extremity of the Wolffian body, it has hardly, by the fourteenth day, reached

as far as either the kidney or genital mass. If anything, it is nearer the lower extremity of the latter.

The foregoing account of the course of events in rabbits' embryos has been given because those animals afford material of a fairly trustworthy character, and useful for checking that derived from human embryos. In endeavouring to ascertain how far that which they have taught is applicable to human embryos, the following points will be kept in view, namely, to ascertain the relations of the genital mass and Wolffian body to the kidney, and the relations of the genital mass, Wolffian bodies, and kidneys to the skeleton.

Earliest Relations of the Human Reproductive Glands and Urinary Organs to each other and to the Skeleton.

Although I have been unable to obtain human embryos suitable for showing each stage in the development of the permanent kidneys, yet there is little doubt but that those organs begin the same as in the rabbit. For instance, in a human embryo whose hind limbs had just budded, and whose development was almost equivalent to that of a rabbit's embryo of the thirteenth day, the permanent kidneys lay behind the lower end of the Wolffian body and genital mass, and it was evident from their rudimentary structure that they had just appeared. Moreover, in sections through the lower end of the Wolffian body, the acetabular portion of the cartilaginous pelvis and the cartilaginous femur could be seen.

The observation that the human pelvis is developed in a solid mass of mesoblast opposite the lower end of the Wolffian body is borne out by other specimens, and they also show that the iliac cartilage grows upwards behind the end of that organ. In these respects the human embryo resembles the rabbit, and there can be no question but that its Wolffian body is likewise in relation with the venter of the pelvic cartilage, because of the manner in which the cartilage develops and grows, and not on account of movements which the excretory organ may have undergone.

Another human embryo a little more advanced, and which was estimated to have reached about the fifth week of intra-uterine life, has been mentioned in which the kidney lay behind

the genital mass and Wolffian body, much in the same way as it did in the rabbit (fig. 31, Pl. II.). So that, up to this point, there seems to be no difference between rabbits and human embryos.

In a human embryo of the seventh week, which has been frequently mentioned, and whose reproductive organs have been figured (fig. 39, p. 61; also fig. 34, Pl. II.), the various features are shown so clearly that it is proposed to describe them in greater detail.

The section which has been figured (fig. 46) is to the left of the vertebral column, and in its lower part divides the cartilaginous ilium and ischium, and a portion of the femur; in its upper part, amongst other things, the twelfth rib and diaphragm are in view. The histological structure of the kidney is very rudimentary, and that organ lies betwixt the last rib and the crest of the ilium, and almost equidistant from either of those landmarks. Only the lower end of the Wolffian body has been divided in this section, but, as in the case of the rabbit, it lies upon the venter of the ilium, and reaches as low as the head of the femur.

In sections near the mesial plane the main part of the genital mass is just below the kidney, and on a level with the crest of the ilium (fig. 46), whilst its upper part, together with the sexual portion of the Wolffian body, extends along the convex margin of the kidney almost as far as the twelfth rib. It might easily be supposed that these appearances indicated that the genital mass had actually moved to a lower place in the abdomen, and this would be the more easily inferred if nothing but its relation to the kidney were taken into consideration. In a moment we shall see that its relations to the Wolffian body and to the skeleton have undergone no alterations which ought to be attributed to any process of locomotion, although it is probable that its relations to the kidney have become modified owing to the manner in which either organ develops. For instance, it seems possible that the part of the genital mass which is nearest the lower end of the kidney takes a greater share in the formation of the reproductive gland than the upper part. This seems to be so in rabbits of the latter part of the thirteenth day, and also in rats of a similar degree of develop-

ment. In both of these the lower portion of the genital mass is much more bulky than the upper, and if the same holds good for human embryos, as it seems to do in the one we are discussing, it would naturally help to explain the relative positions of the organs to one another. Before mentioning the growth of the permanent kidneys, it is convenient to ascertain whether the Wolffian bodies have altered their relations to the newly formed cartilaginous skeleton; for it seems safe to assume that, if those organs have kept their position, the genital mass must have done the same.

I have already pointed out that the relation of the Wolffian body to the pelvis is determined by the manner in which that part of the skeleton develops behind its lower end. In the human embryo of the seventh week, which is being described, the acetabular portion of the pelvis occupies its original position at the lower end of the Wolffian body, although, as in the rabbit, the upward growth of the iliac cartilage makes the sexual organs look lower than they might otherwise do. Judging from its relations to the kidneys, the urinary portion of the Wolffian body seems decidedly lower in the abdomen. This, however, may be partially accounted for by the way in which the temporary and permanent urinary organs grow in relation to each other. Although the kidneys first appear behind the lower end of the Wolffian body, yet their growth seems to be upwards towards the head rather than downwards. Moreover, as we have seen, before the kidneys have attained much size or perfection, this so-called urinary portion of the Wolffian body increases, and tends towards the pelvis. These factors, taken together, seem almost sufficient to account for the relative positions which the kidneys and Wolffian bodies have assumed.

If we recall the early history of the Wolffian body, it is clear that its sexual portion still remains to be accounted for. This, in the specimen which is being described, is applied to the uppermost part of the genital mass (fig. 34, Pl. II. Lect. II.), and lies outside the kidney, and above the level of the iliac crests. Therefore, it may be concluded that although the sexual portion of the mesonephros is undergoing changes, it has not altered its original position, but that various parts of the

skeleton and the kidneys themselves have developed and grown in its proximity.

Relation of the Mesonephros to the Suprarenal Bodies.

Should this line of argument be thought wanting in cogency, another circumstance may be mentioned which seems to show that neither the temporary kidneys nor their adjuncts, the genital masses, have altered their positions. In speaking of the sections through the inner part of the Wolffian body of this seven weeks' embryo (Lect. II. p. 71), it was said that " the foremost glomeruli, although larger, are faintly stained, and their tissues granular,—appearances which indicate that they have begun to degenerate and atrophy." When this was written I felt uncertain whether this portion of the Wolffian body was continuous with the lower and inner part of the suprarenal body. It is so easy in histological specimens to fancy structures are continuous which merely overlap, that I refrained from making any statement upon the subject. However, after studying the specimens over and over again during many months, I am of opinion that a portion of the mesonephros of this human embryo is in actual continuity with the suprarenal bodies. The part in question is that which is nearest the mesentery, and which, as has been repeatedly said, is mainly composed of glomeruli. It reaches the lower and inner part of the suprarenal along the course of the ureter, and towards the upper part of the hilum of the kidney, but quite separate and distinct from the substance of that organ. Not only am I unable to discover any line of demarcation between the glomerular part of the mesonephros and the suprarenal body, but those organs seem to merge gradually into one another; this is seen best by observing the glomeruli, which, whilst being quite distinct below, become fainter and more finely granular as they merge into the suprarenal (fig. 47). The main bulk of the latter is composed of small nucleated cells, arranged in the well-known radiate columns seen in the adult organ. Between these columns there is a supporting stroma, which is directly continuous with that of the Wolffian body, which, it may be remembered, has already been depicted and described (Lect. II. Pl. II., fig. 24, and also p. 45). Towards the centre of the suprarenal body the radiate

arrangement of its elements ceases, and instead are loculi of cells more loosely aggregated, and of larger size and oval.

...Suprarenal Body.

Pancreas......

......Kidney.

Wolffian B...

Ureter..........
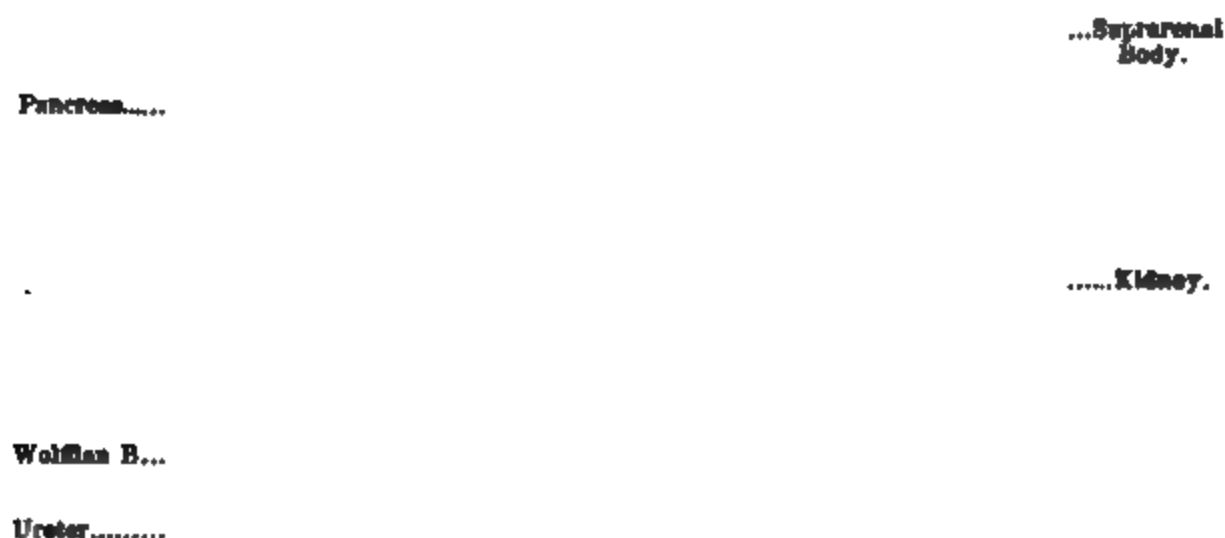
Fig. 47.—Continuity of Wolffian and Suprarenal Bodies in a Human Embryo of the seventh week.—(Electrotype from photograph of section.)[1]

The cortical portion ·of the suprarenal body of this seven weeks' human embryo has an exceedingly strong likeness to the neighbouring genital mass in the following respects, namely, in the radiate arrangement of its cell elements, their size, shape, and staining, and also in the character of its stroma; although the last can only be considered a minor and perhaps unimportant point of resemblance.

In due course I propose to discuss the position and relations of the sexual apparatus of another human embryo, which has been mentioned before, and which was estimated to have attained the tenth week of intrauterine life (Lect. II. fig. 40, p. 65). But, before commencing this topic, it is convenient to inquire whether it in any way confirms the statements which have just been made concerning the relation of the mesonephros to the suprarenal bodies.

[1] I am indebted to my friend Mr Cosens for the micro-photograph from which this electrotype was made.

In this embryo the kidneys lie opposite the lumbar spine, and their position is the same as in the younger specimen (fig. 40, Lect. II. p. 65). The suprarenal bodies are much larger than the kidneys, and occupy their usual position above those organs. Their lowest part reaches downwards a little beyond the hilum of the kidney. The testicle (for in this case the tunica albuginea and tubuli seminiferi have appeared (fig. 41, p. 66, Lect. II.)) and the Wolffian body, or, as it has almost become, the epididymis, lies just below the kidney and upon the venter of the iliac cartilage. In the section which has been figured there is not the slightest connection between the Wolffian body and the suprarenal body, but it may be remembered that in the younger embryo the junction between those organs was effected near the hilum of the kidney by a process of glomerulus containing tissue which lay along the course of the ureter. Now, in the sections which divided that canal, there were in its neighbourhood structures which had all the appearances of those granular and altered glomeruli seen in the previous instance. Moreover, the lowest part of the suprarenal body extends so far into the hilum of the kidney, that although it is hard to tell whether in any particular section it is continuous with the peri-uretral glomerular tissue, nevertheless there is little doubt but that such is the case. But, in addition, the appearances of the lowest part of the suprarenal body are exceedingly significant. In every part of its circumference that organ has a very definite fibrous capsule, which delimits it from surrounding structures, except below, where its continuity is broken. In that region it is, I think, certain that some of the glomerular structures, such as lie along the course of the ureter, are imbedded in the cortex of the suprarenal body. In this older embryo the difficulty of arriving at a correct opinion upon this point is increased owing to the large size of the renal veins; but, nevertheless, the suprarenal body seems still connected with the Wolffian body, although the passage of the renal veins through the peri-uretral tissue renders their continuity harder to determine. I may add that there is not the slightest trace of any mixing of the renal tissues with those of the Wolffian body; on the contrary, the kidney has a definite capsule. Supposing these observations are correct, it

is quite unnecessary to comment upon their importance. The recent observations of Mr Weldon[1] seem to show that there is in some types a close relationship between the early development of the suprarenal bodies and the glomeruli of the mesonephros. Also Janošik[2] has found that the suprarenals develop in connection with the foremost part of the urogenital ridge.

The human embryos of the seventh and tenth weeks, which have just been described, seem to indicate that the human suprarenal body has a developmental relation to the inner and upper part of the mesonephros. Doubtless the appearances of the glomeruli of that organ in the younger embryo indicate that an atrophic process has begun by which the mesonephros becomes eventually disconnected from the suprarenal; and it seems as if, in the older specimens, that disseverance was almost accomplished; and to this consummation the growth of the permanent kidneys and of their veins seems to have conduced.

The bearing of the foregoing upon the question whether the Wolffian body and genital mass of the seven weeks' human embryo has descended in the abdomen or not can easily be inferred. Judging from their relations to the skeleton, it has already been decided that the sexual and urinary portions of its Wolffian body have undergone no actual alteration in position; and now it may, with plausibility, be urged that the connection of its inner and upper part with the suprarenal body would render such movements exceedingly improbable.

The human embryo of the tenth week is the earliest I have obtained in which the sex is not doubtful. It is hardly requisite to recapitulate the grounds upon which it has been decided that it is a male; the existence of the tunica albuginea testis, and unquestionable tubuli seminiferi are perhaps the most important. Therefore it is of especial interest to endeavour to ascertain whether, in this instance, the testicle and epididymis have undergone any active process of transition towards the lower part of the abdomen, or whether these organs have maintained the position which was determined for them by the development in their proximity of the kidneys and pelvis.

[1] "On the Suprarenal Bodies of the Vertebrata," W. F. R. Weldon, *Quart. Jour. Micr. Sci.*, vol. xxv. p. 137, 1885.

[2] "Bemerkungen über die Entwicklung der Nebenniere," *Archiv für Micros. Anatomie*, Band xxii., 1883, p. 738 *et seq.*

As regards the relation of the Wolffian body to the pelvis, some of the sections show that its urinary part is opposite the acetabular portion of the pelvis, and therefore has undergone no change since that part of the skeleton was developed in its vicinity. Also, it may be mentioned that the hypogastric arteries have attained considerable size, and project so far into the peritoneal sac that they almost touch the right and left genital strings, just after the latter have left the Wolffian bodies. Later in embryonic life it is probable that those vessels have an influence in determining the point at which, in the male, the sexual glands pass through the abdominal wall.

Although, therefore, the testicle and epididymis of this ten weeks' embryo have maintained their original relations to the pelvis, yet, apparently, their relations to the kidneys have altered. This is due, as in previous instances, to (a) changes in the reproductive organs themselves, and (b) to changes in their surroundings, including the kidneys. It is convenient to begin with the last mentioned; and, in the first place, it seems improbable that the appearances can be due to any movements of the kidneys. In the seven weeks' embryo those organs were situated opposite the lumbar spine, and now, at the tenth week, they still occupy the same position. In the interval, however, they have grown, and instead of being subordinate to the sexual organs they now surpass them. This circumstance has clearly an influence in determining the relation of the genital glands to the kidney.

The growth of the lumbar spine is also a factor which must be taken into consideration in speaking of the influence which the growth of their surroundings may have upon the apparent position of the reproductive glands. Although, at the tenth week, the lumbar spine has grown a great deal, yet it has only kept pace with the growth of its contents and surroundings. The spinal medulla still extends the whole length of its canal (fig. 40, p. 65, Lect. II.), and the cauda equina and filum terminale are non-existent. In older embryos the growth of the spinal column is so rapid that it far outstrips that of the spinal medulla, and, as is well known, leads to the formation of the last-named structures. Now, it is significant to observe that whilst the spinal column, especially of its lumbar part, is

growing, the genital gland, either ovary or testis, separates from the kidney. During this separation the kidney remains immobile in front of the lumbar spine, and the sexual gland maintains its original relation to the pelvis, so that one important cause of the separation is not far to seek, and is, in my opinion, the growth of the lumbar spine.

We may now return to the human embryo of the tenth week, with a view of ascertaining whether any changes in the sexual gland and Wolffian body may have helped to bring them into position below the kidney.

It cannot be considered to have been proved that, in the human embryo, the lower part of the sexual eminence is actually converted into the testicle, but, nevertheless, that is possibly the case; and I have already argued that the circumstance may partially account for the position of the genital mass in the embryo of the seventh week. In the present instance the genital mass has become the body of the testicle, and that organ is decidedly globose, and has ceased to extend around the outer convex border of the kidney, as it did at the earlier stage. Also, the sexual portion of the Wolffian body has become more closely applied to it, to form the epididymis. These circumstances, together with the incorporation of the upper and inner part of the Wolffian body in the adrenals and its partial atrophy, help to determine the position of the sexual glands below the kidneys.

The development of the ovary is not at present in question, but perhaps I may mention that the foregoing observations are, in all probability, applicable to either sex. An exception to this statement must be made in respect to the shape of the ovary, for that organ does not become globular like the testicle, but retains to a certain degree the primitive elongated form of the sexual eminence.

In the human embryo of the twelfth week, and whose testicle has been figured (fig. 33, Pl. II. Lect. II.), that organ, as usual, lay in front of the ilium, and upon the brim of the pelvis; its lower part almost touched the hypogastric arteries, whilst its upper end is just in contact with the kidney. At this age the body of the testicle seems longer than the epididymis, and the latter has no upward prolongation. So far as concerns

its relation to the pelvis, the sexual gland is almost in the same position as it was in embryos of the seventh and tenth week; but its mesentery is much longer than it was in them, and it is altogether more separate and distinct. Judging from the length of the spinal cord, the vertebral column has not grown very much, and has, so far, merely kept pace with the growth of the organs in its vicinity.

At the third month the position and connections of the testicle may be observed by ordinary dissection and with the naked eye. The sex of the embryo may also be ascertained in the same way by the shape of the sexual gland, and, more especially, by the direction of its long axis. In males the long axis of the testicle is vertical and its shape globular; whilst in females the long axis of the ovary is oblique, and the gland is decidedly spindle-shaped. It is hardly necessary to add that the external organs of generation are at this period the same in either sex, and therefore of no value for determining the sex.

Before proceeding, it may be advisable to enumerate the events which seem to participate in leaving the testicle or ovary upon the brim of the pelvis. I will endeavour to give them in their proper sequence. 1. Development of mesonephros. 2. Development of genital eminence. 3. Development and growth of kidney behind mesonephros and genital eminence. 4. Development and growth of pelvis behind lower end of mesonephros. 5. Alterations in upper part of mesonephros; its partial atrophy and probable incorporation in suprarenal capsule. 6. Growth of lumbar spine.

EXPLANATION OF PLATE XVII. AND OF WOODCUTS.

Fig. 42. Opening of oviduct of embryo pig into peritoneal cavity. *Ov.*, oviduct ; *W.B.*, Wolffian body ; *Lng.*, lung ; *M.*, mesentery.

Fig. 43. Oviduct, where its lumen begins. Letters the same as fig. 42. *I.P.*, inner process ; *W.G.*, Wolffian glomeruli.

Fig. 44. Oviduct near it hinder end. Letters the same as figs. 42 and 43. *O.D.*, oviduct ; *G.M.*, genital mass.

Fig. 45. *A*, *B*, and *C*, testicles of human fœtuses ; *P.V.*, plica vascularis ; *O.D.*, remains of oviduct ; *S.Hy.*, spatulate hydatid. *Hy.*, hydatid of oviduct.

Fig. 46. Pelvic and lumbar regions of a human embryo of seventh week; *R.*, ribs. 11th and 12th; *Sup. R.*, Suprarenal body; *K.*, kidney; *G.M.*, genital mass; *W.B.*, Wolffian body; *Il.*, ilium; *Isch.*, ischium; *Fem.*, femur; *Glut.*, gluteus maximus; *St.*, stomach.

Fig. 47. Electrotypes from micro-photo to show continuity of Wolffian body suprarenal (page 470).

Fig. 48. Human embryo of three months to show plica gubernatrix and position of testis; × 3. *T.*, testicles; *K.*, kidney; *I.*, intestine; *P.V.*, plica vascularis; *G.C.*, right and left genital cords; *C.G.C.*, common genital cords; *B.*, bladder; *Gub.*, plica gubernatrix and gubernaculum.

Fig. 49. Mesorchium and its folds (p. 60; woodcut).

Fig. 50. Ostium of processus vaginalis at fifth month. *Tes.*, testicle; *V.D.*, vas deferens; *Gub.*, gubernaculum; *P.G.*, plica gubernatrix; *P.V.*, processus vaginalis; *C.*, loose cellular tissue; *Il. Ves.*, iliac vessel; *Int. Ob. and Trans.*, internal oblique and transversalis muscles; *Ex. Ob.*, external oblique.

Fig. 51. Processus vaginalis in transverse section. Letters same as fig. 50 (woodcut).

Fig. 52. Unattached gubernaculum (woodcut).

Fig. 53. Gubernaculum of six months' foetus. The peritoneum has been dissected from psoas and iliacus, and turned over the bladder in order to show the gubernaculum upon its outer surface; *P.*, peritoneum; *Ant. S.I.*, anterior superior spine of ilium; *B.* bladder; *Hy. A.*, hypogastric arteries; *T.*, testicle; *G.*, gubernaculum; *Ps.*, psoas; *Il.*, iliacus; *Int. Ob.*, internal oblique.

Fig. 54. Diagram constructed from sections and dissections of human foetuses at full time. To show peritoneal, scrotal, and perineal prolongations of the gubernaculum testis; *Cæ.*, caecum; *P. Vag.*, processus vaginalis; *P.*, pubic bone; *Pl. Vas.*, plica vascularis; *Ep.*, epididymis; *Tes.*, testicle; *Pl. Gub.*, plica gubernatrix; *Gub.*, gubernaculum; *Per.*, perineal fibres of the gubernaculum testis.

Fig. 55. Infantile hernia to show the band of muscular fibres passing from epididymis to sac of hernia (woodcut).

Fig. 56. Processus vaginalis at eighth month of intra-uterine life to show the relations of the vas deferens and spermatic vessels to its posterior wall; *S.V.*, spermatic vessels; *V.D.*, vas deferens; *Ep.*, epididymis; *Tes.*, testicle; *Gb.*, gubernaculum.

Fig. 57. Recurring branches of spermatic artery; *S. A.* and *V.*, spermatic artery and vein; *S.*, sigmoid flexure.

MICROSCOPICAL EXAMINATION OF CLARKE'S COLUMN IN MAN, THE MONKEY, AND THE DOG. By FREDK. MOTT, M.D., B.S. Lond., M.R.C.P., *Lecturer on Physiology and Medical Registrar, Charing Cross Hospital.*[1]

THIS column of cells has lately excited considerable interest on account of the very important and original paper by Dr Gaskell "On the Nerves of the Visceral and Vascular System." Both Dr Ross and Dr Alexander Hill had previously suggested that the cells of Clarke's column were connected with the innervation of the viscera; but Dr Gaskell proved the outflow of the fine medullated fibres of the visceral and vascular system to agree in position exactly with the cells of Clarke's column in the spinal cord. No anatomical connection has been proved between these fibres and the cells. The older view of Flechsig is, that they are connected with the innervation of the trunk muscles. One fact in connection with these cells is pretty well established, and was first shown by Lockhart Clarke, namely, that these cells are connected with the fibres of the direct cerebellar tract. The subject is one of great interest, both physiologically and pathologically, and I have examined a great number of sections with a view of ascertaining whether any new light can be thrown upon it. The materials which have been used were as follows:—The spinal cord of a healthy boy, who died from injury; ditto of a healthy bonnet monkey; ditto of a small young dog; also that of a full-termed fœtus; added to these a number of pathological specimens bearing on the subject.

The tissues were hardened in 2 per cent. solution of bichromate of ammonia, subsequently in alcohol, and then sections were cut of nearly uniform thickness, both transverse and vertical, of each segment of the cord. The sections were made by means of a freezing microtome, and stained by the Weigert method. Each section was examined with a view of determining the situation,

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[1] An abstract of this paper was read and specimens and micro-photographs were shown to the Anatomical Society, November 22, 1887 (*Proceedings in Jour. of Anat. and Phys.*, Jan. 1888).

distribution, and number of cells, and the size of the column in each segment of the cord.

I. Situation, Size, and Relative Number of Cells.

In Man the column is a cylindrical body situated at the neck of the posterior horn, projecting on the postero-external column and behind the central canal. The shape is ovoid, with the long axis from before back (see fig. 1). It was found well marked

Fig. 1.—Transverse section of Clarke's column at level of 1st lumbar. The large branched multipolar cells are seen lying in a network of fibres. Fibres are seen passing in from the postero-external column. The fibres passing out of the column to the direct cerebellar tracts are not clearly shown in this micro-photo, although the section shows them very distinctly. (Magnified 60 diameters.)

in all the sections, from the 8th dorsal to the 2nd lumbar inclusive. Above this, up to the 6th dorsal, many of the transverse sections showed cells, but in a great many only transverse sections of fibres and of a fine nerve plexus were to be seen. From the 6th dorsal up to the 2nd dorsal it was very difficult

to determine, by examination of *transverse* sections, the existence of the column; but occasional sections would show a few cells. *Vertical sections*, however, showed scattered groups of cells up to the 1st or 2nd dorsal. None could be seen in the cervical enlargement, but in the 1st to the 3rd cervical a few scattered cells could be seen, not forming a definite column, as in the lower dorsal region. Cells are not found below the 2nd lumbar, with the exception of a few in the upper sacral, cor-

FIG. 2.—Transverse section of spinal cord of Monkey at 7th dorsal. The column is seen distinctly on the left of the central canal; it has a circular form, and contains four cells in section. On the right fibres are seen passing to the column from the postero-external column. (Micro-photograph magnified 60 diameters.)

responding to Stilling's nucleus. Vertical sections showed in the lower dorsal and upper lumbar region a continuous column of cells; hence all transverse sections would show the cells in this region. On the contrary, in the *upper* dorsal region the cells do not form a continuous column, but are often found in segmental groups, more frequently scattered irregularly, and always arranged, in this situation, with their long axis vertical.

Size of column.

1st lumbar,	. . .	1 mm. × ·7 mm.
12th dorsal,	. . .	1 „ × ·7 „
8th „	. . .	·7 „ × ·65 „
Mid „	. . .	·4 „ × ·3 „

Higher than this could not be estimated.

From the 8th dorsal to the 2nd lumbar the number of cells in the transverse section on either side varies from 8 to 20. In the micro-photograph, fig. 1, the number is 14.[1]

In the Monkey the column forms a cylindrical body on either side of the central canal, separated from the posterior column by a considerable interval (except in the last dorsal and upper lumbar), across which fibres pass to it[2] (see fig. 2).

In the Dog the situation of the column corresponds to that previously described in the Monkey. It seems, however,

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[1] An important fact may be mentioned now, that as the column increases in size and distinctness, so also are the cells larger, corresponding in this respect to the anterior cornua. It may be mentioned that the cells of Clarke's column are more numerous than the anterior cornual cells in the lower three or four dorsal segments.

[2] 1st cervical, 2 or 3 cells on each side in some sections.

2nd	„	2 or 3	„	„	„	
3rd	„	4	„	„	„	
4th	„	2	„ on one side in one section (not very characteristic.)			
5th	„	None.				
6th	„	„				
7th	„	„				
8th	„	„				
1st	dorsal,	1 or 2 cells on each side in same section.				
2nd	„	size ·2 × ·15 mm.,	2 cells on each side in 4 to 6 sections.			
3rd	„	„ „	3 „	„	„	„
4th	„	„ „	4 (average) „	„	,	
5th	„	„ „	4 „	„	„	„
6th	„	„ ·2 × ·8	numerous (about 7).			
7th	„	„ ·4 × ·2	„			
8th	„	„	6 to 10 cells			
9th	„	„	„			
10th	„	„ ·5 × ·2	„			
11th	„	„ ·5 × ·3	„			
12th	„	„ ·6 × ·3	„			
1st lumbar	„	·7 × ·6 numerous.				
2nd	„	„ ·4 × ·3 not so numerous.				

Below this (with the exception of Stilling's nucleus) there are no cells to be found.

to be better marked in the upper cervical and upper dorsal region.[1]
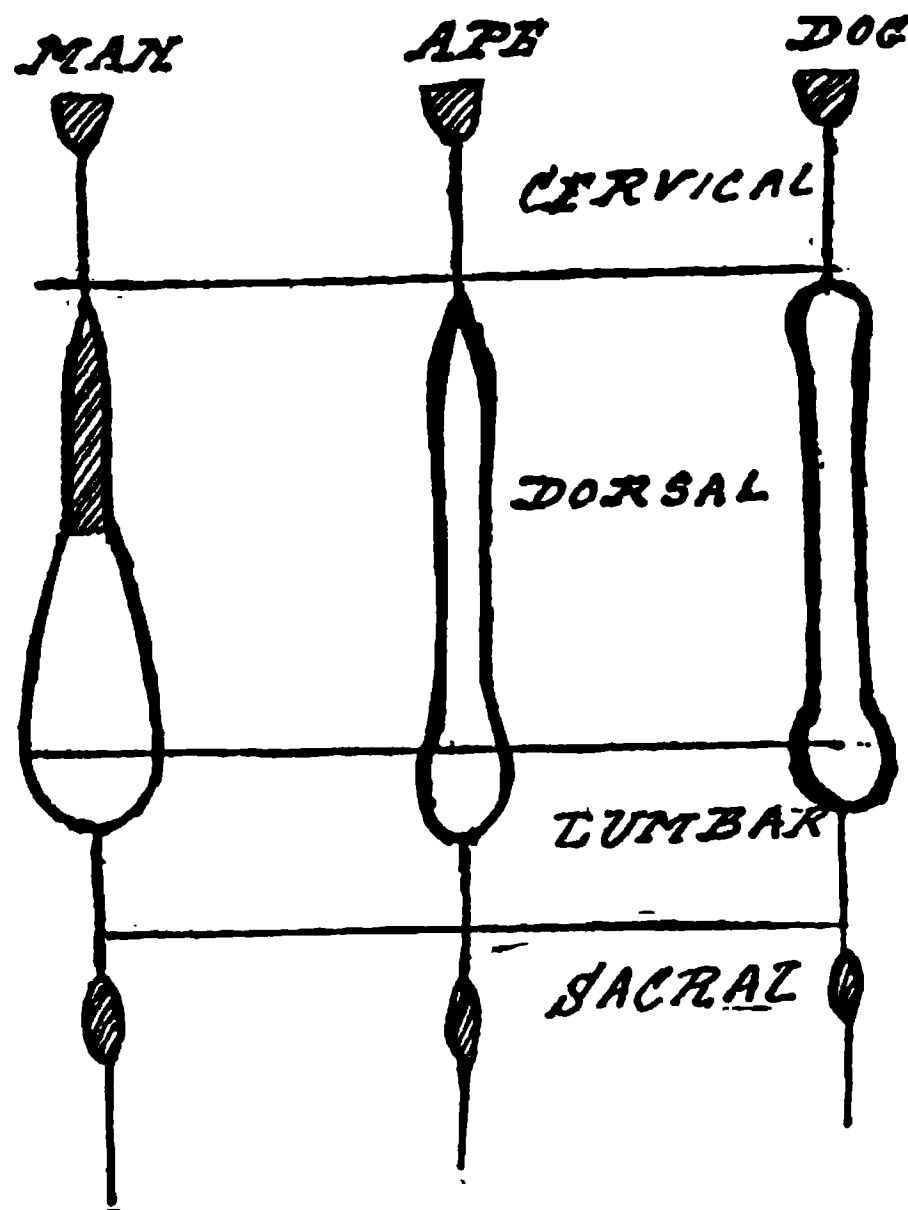
The statistics in the footnotes, together with those already

[1] 1st cervical, column not defined, few cells on each side.

2nd	,,	,,	,,	,,
3rd	,,	,,	,,	,,
4th	,,	nil.	none.	
5th	,,	,,	,,	
6th	,,	,,	,,	
7th	,,	,,	,,	
8th	,,	,,	,,	

1st dorsal, few cells on each side.

2nd	,,	size ·3 × ·3 mm., 3 to 6 cells on each side.		
3rd	,,	,,	,,	,,
4th	,,	,,	4 to 5	,,
5th	,,	·3 × ·2	,,	,,
6th	,,	,,	3	,,
7th	,,	,,	3 to 4	,,
8th	,,	,,	·,	,,
9th	,,	·3 × ·15	,,	,,
10th	,,	,,	,,	,,
11th	,,	·3 × ·3	4	,,
12th	,,	,,	3 to 4	,,
1st	lumbar	·6 × ·35	6	,, } very distinct and large.
2nd	,,	,,	,,	,,

Below this only a few cells could be made out about the 2nd sacral.

stated in connection with the column in Man, allow of a diagram, such as the one represented on p. 481, to be made. This is intended to show the situation and size of the column in the cords of these three animals. A glance at it shows at once that the cells are not distributed in the same manner in all of them, and the Monkey apparently stands between the other

Fig. 3.—Portion of same section as fig. 1, showing form of cells. The network of nerve-fibres from postero-external column, in which the cells lie. One large multipolar nerve-cell, with large processes, is seen. (Micro-photograph, magnified 200 diameters.)

two. I may suggest that this difference in the distribution of the cells in the Dog, as compared with Man, may be related to the fact of the erect posture of the latter. I am engaged at present in determining whether, in the upper part of the spinal cord of Man, where Clarke's column is apparently slightly developed, there is a corresponding disparity in the fine efferent medullated fibres which Dr Gaskell has shown to emerge from the cord in the Dog in such numbers from the 2nd dorsal segment downwards.

II. THE NERVE CELLS, FIBRES, AND OTHER STRUCTURES CONSTITUTING CLARKE'S COLUMN.

Transverse sections of the cord in those regions where the column is well marked show the following structure:—Numbers of the cells are arranged with the long axis vertical; however, in the lower dorsal and upper lumbar regions, particularly in Man, transverse sections show many cells of a vesicular form and with the long axis looking horizontally forward (see micro-photo, figs. 1 and 3). Many of these cells are seen to be multi-

Fig. 4.—Micro-photograph of a section of Clarke's column at the 10th dorsal segment. Close inspection shows numbers of fine fibrils passing from the spongy network to the cells. The cells for the most part appear to be bipolar. A rather small cell to the right, however, has two processes coming off from the lower end. (Magnified 200 diameters.)

polar, giving off large and distinct cell processes, some of which again divide and branch, something like an anterior-cornual cell, except that the processes are not so numerous. Other cells are seen cut more transversely, so appear oval or round. They are seen to lie in a plexus of nerve-fibres which come in

from the postero-external column. A number of medullated nerve-fibres can be seen also in transverse section. Many of the cells lie right out amid the fibres of the postero-external column (see figs. 1 and 3), but no anatomical connection can be traced. Vertical sections, as illustrated by the accompanying micro-photograph (fig. 4), show most of the cells to be arranged with the long axis vertical, the nucleus being in the centre of the cell and very distinct. The cells are of unequal size, most of them being bipolar, vesicular, or fusiform. They lie in a network of very fine fibrillæ, which seemed to me, upon accurate focussing in well-prepared sections, to have a protoplasmic continuity

Fig. 5.—Drawn from micro-photos magnified 200 diameters. *I.*, Cells of Clarke's column at last dorsal and 1st lumbar ; *II.*, Smaller fusiform cell from 8th dorsal vertical section ; *III.*, Average-sized anterior cornual cells of lumbar and cervical enlargements ; *IV.*, Cells from vagal nucleus.

with the cells.[1] The processes which the cells give off are large, and soon acquire a medullary sheath. This accounts for the nerve-fibres seen in the transverse sections. The size of the cells varies considerably according to the situation, the average size at the 8th dorsal being ·05 mm., the average size at the 12th dorsal being 1·09 mm. in longitudinal sections. Schwalbe gives the measurement as ·045–·9 mm. In vertical

[1] This connection of fine fibrillæ with the cells is seen in careful prints of the micro-photographs.

sections where the cells are not very numerous they are often seen arranged in segmental groups. It should be mentioned that the general direction of the fibrillæ, in which the cells are, as it were, imbedded, is vertical. The accompanying diagram (fig. 5) represents outline forms of the cells in Clarke's column, the cells of the anterior cornua of the cervical and lumbar enlargements, and of the vagal nucleus. They are traced from microphotographs, taken under exactly the same conditions, magnification being 200 diameters. The smaller fusiform bipolar cell is somewhat similar in shape and size to the cells of the

Fig. 6.—Transverse section of Clarke's column in lower dorsal region of full-term fœtus. Fibres seen passing from postero-external column to the group of cells. (Magnified 100 diameters.)

vagal nucleus. The multipolar cell, which is taken from the previous representation of Clarke's column, is the form of cell most frequently met with in transverse sections of the lower dorsal and upper lumbar region. It is $\frac{1}{10}$ mm. in length, and compares favourably in size with the cells of the anterior cornua. Moreover, the processes given off are large, and one in particular, which evidently will form an axis-cylinder of a nerve, is very large. In some respects there is a similarity in form of

these cells to the cells of Purkinje of the cerebellum, a process being given off from the rounded extremity and the other pole ending in a branching process.

I may say that the cells of the anterior cornua figured here were average-sized cells of the lumbar and cervical enlargements. If large cells are connected with large fibres, and we know they are in the case of the anterior roots, I do not see how these large cells of Clarke's column cells can be associated with the small medullated fibres described by Dr Gaskell. There is very good reason, however, for believing them to be connected with the fibres of the direct cerebellar tract.

In the Monkey and the Dog the cells are not quite so large, although both vertical and transverse sections show the same form.

Fibres.—Transverse sections of the cord in the Dog and the Monkey show fibres passing upwards and forwards from the postero-external column to Clarke's column. Owing to the position of the column in the cords of these animals, these fibres are seen distinctly passing across the grey matter intervening between the central canal and the posterior column (see fig. 2). In the human spinal cord (see fig. 1) fibres may be seen running from the root zone of the postero-external column into Clarke's column; another set of fine fibres may be seen running from the outside of Clarke's column, and sweeping round the neck of the posterior cornu to form the posterior commissure, while another set of fibres is seen to pass in at the posterior part of the column and along the inner side. These fibres encircling thus limit the column.[1] The accompanying micro-photograph, fig. 6, is a section of the lower dorsal cord

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[1] Bechterew (*Archiv für Anatomie*, Heft ii. and iii., 1887), from an examination of the spinal cords of new-born children and fœtuses, divides the fibres of the posterior roots into two divisions,—an outer, consisting of fine fibres, and an inner bundle of larger fibres. The majority of the latter go into the antero-external part of the postero-external column. A smaller number pass immediately into the substantia gelatinosa Rolandi. Many of the fibres run upwards into the antero-external part of Burdach's column, then again take a horizontal direction in order to enter the grey substance of the posterior horn. These fibres pass from the root-zone directly into Clarke's column. He represents three sets of fibres passing from Clarke's column, the most considerable being directed outwards behind the lateral horn to the direct cerebellar tracts. Other fibres, he says, go to Goll's column, while a third set passes to the anterior horns,

of a full-termed fœtus. It shows, though not so distinctly as the specimen, fibres passing out from the postero-external column to the cells of Clarke's column. So far, no anatomical connection has been traced between the fibres of the posterior roots and the ganglion cells of the cord; but we should not expect such if we adopt the theory that the cells of the posterior ganglion on the root give off two processes, as in fig. 9, the fibres of which terminate at one extremity in a plexus or sense organ of the periphery, and at the other in a delicate plexus around the ganglion cell, with which the fibre is connected in the cord. This is one view as to the connection of

Fig. 7.

the cells in Clarke's column, but of course it does not correspond with that held by Dr Gaskell. There are certain arguments, however, in its favour, afforded by pathological considerations, to be treated of later. With regard to the connection of the cells above we have more definite evidence. Lockhart Clarke first showed this connection, and Henle, Schwalbe, Flechsig, and Gowers have supported his views.

Vertical sections of the cord show, wherever Clarke's column is present, numbers of fibres passing out transversely through the cross-pyramidal tract to the direct cerebellar tract, as in fig. 7, drawn from micro-photo. The fibres are comparatively large, as indeed they are in the direct cerebellar tract. Whether all these fibres reach the cerebellum or not is a question. Lockhart Clarke showed that the cells gave off fibres which could be traced outwards to the cerebellar tract, and both transverse and vertical sections show this, although it is very difficult to trace a fibre from a cell any distance. I believe this to be due to the fact that the process given off from the cell, after it has acquired a medullary sheath, runs upwards some distance, and then forwards and outwards, so that it would be impossible in a vertical or transverse section to trace any individual fibre some distance from the cell from which it originated.

III. Pathological Conditions of the Spinal Cord.

The following cases of disease, from which specimens were prepared, tend to throw light upon the subject:—

1st. Cases of Injury to the Roots of the Cauda Equina.— (a) J. H., aged 51; occupation, clerk; suffering with locomotor ataxy. The affection began ten months previously with difficulty of micturition, followed by weakness in the legs; difficulty of walking, especially in the dark; vomiting, which had lasted three or four months; absence of superficial reflexes in lower extremities; absence of patellar reflexes; Argyll Robertson pupils; grey atrophy of discs; impaired sensation in both legs. This patient remained under observation a considerable time, and died eventually with laryngeal crisis. At the *autopsy*, on opening the spinal canal, the dura mater was observed adherent to the body of the 3rd lumbar vertebra, in which there was extensive caries. There was also a similar condition, though to a less degree, in the last dorsal. *Microscopical examination* of the spinal cord revealed thickening of the membranes, degeneration of the nerve roots of the lower part of the cord, ascending degeneration in the postero-external column, well marked in the lower dorsal, but diminishing the higher we get in this region. Posterior median affected throughout the cord.

There was no marked sclerosis of the direct cerebellar tract (fig. 9, I).

Upon examining sections with a high power, the cells of Clarke's column were still seen to be present, but many of the sections showed the fine network of nerve fibrillæ to be atrophied and replaced by a fine nucleated connective tissue, and bands of sclerosis running into the column in the place of the nerve fibres seen in the normal sections (see fig. 8). In all probability

a ...

b ..

Fig. 8.—Section of Clarke's column in case of injury of roots of cauda equina; sclerosis of postero-external column in lower part; bands of sclerosis passing into the column; an atrophy of the plexus of nerve-fibres, and replacement by fine nucleated fibrous tissue. (Magnified 100 diameters.)

this case began by an inflammatory change in the peripheral nerves, set up by the caries of the vertebræ. Numerous cases[1] have been recorded of injury and tumour of the cauda equina, in which degeneration of the postero-external and posterior median columns as high as the upper dorsal region have occurred; above this, only in the posterior median. (b) Fracture of 2d lumbar vertebra, compression of the nerve roots and lower portion of spinal cord, resulting in degeneration of postero-

[1] Lissauer, Kohler and Schultze, Hughes Bennett.

external, posterior median, and antero-lateral columns, in the lower dorsal region; but in the upper dorsal and cervical (fig. 9, II) only degeneration of the posterior median and antero-lateral.

In the above cases the injury of the cord was below Clarke's column, and therefore the direct cerebellar tract was unaffected.
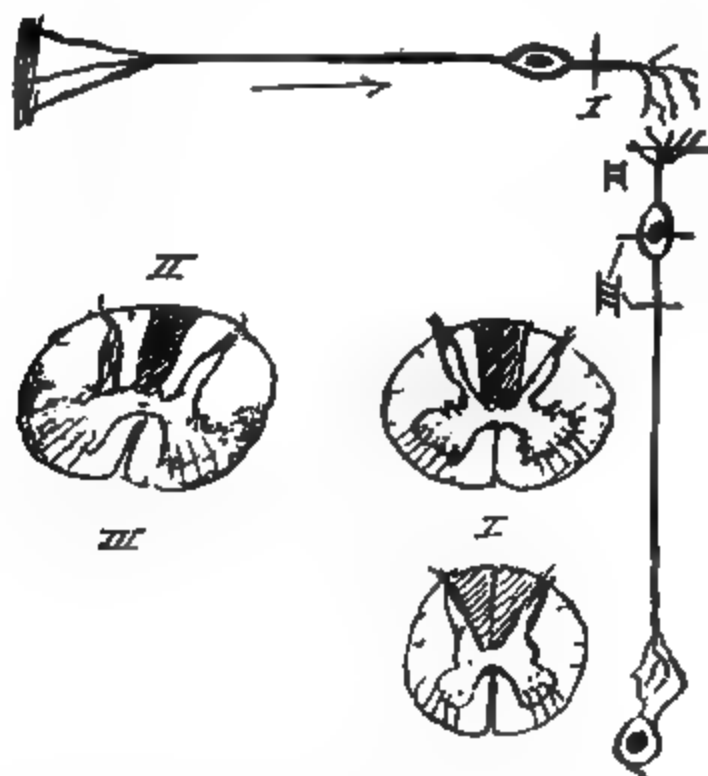

Fig. 9.—This illustrates the various degenerations which occur as a result of—I, injury of roots of cauda equina; II, injury of spinal cord below Clarke's column; III, injury of Clarke's column or the spinal cord above. The transverse sections were made from the cases described.

2nd. Cases of Injury of the Cord in the Region of Clarke's Column.—Two of compression of the lower dorsal cord by malignant tumours, followed by degeneration in the direct cerebellar tract above the point of compression. A third of myelitis, in which the whole grey matter of the dorsal region was involved.—This was a boy, aged 14, who was suddenly seized with a pain in the abdomen, loss of power in the legs, and afterwards of the abdominal and intercostal muscles. Interesting facts bearing upon the subject in hand were the vomiting of a most persistent character and difficulty of micturition and defæcation. The cord showed marked degeneration of the direct cerebellar tracts in the upper cervical region of the posterior median column and of the antero-lateral, but

none of the cross pyramidal tract or of the postero-external fibres, showing that the degeneration of the direct cerebellar tract was not due to a primary lesion of the fibres in this region, but secondary to the atrophy of the cells in Clarke's column below (fig. 9, III).

3rd. Injury of the Upper Segment of the Direct Cerebellar Tract above Clarke's Column.—Degeneration in the direct cerebellar tract invariably takes place when a tumour compresses the cord above the mid-dorsal region.

I have specimens of four cases of local compression without meningitis, but it is not necessary to state details here, as this is a well-known fact (see fig. 9).

IV. SUMMARY.

The facts so far elicited are that Clarke's column is limited, in Man, the Monkey, and Dog, to those regions which Dr Gaskell has shown to give rise to the fine medullated fibres of the visceral-vascular system in the Dog. I think there can be no question that the cells are connected above with the cerebellum. Whether they are connected below (that is in the lower segment) with fibres of a centripetal nature, which come in at the posterior root, as I have shown might be possible, and which is strongly supported by Bechterew's observations, or whether they give rise to the fine efferent medullated fibres, is at present *sub judice*. The form of the cells would support more or less both theories—the homology in situation and form of the fusiform cells to the cells of the vagal nucleus is in favour of Dr Gaskell's theory ; but if the fibres of the direct cerebellar tract are assumed to be in connection with Clarke's column, which I think is fairly well supported, then these cells are in connection above with afferent fibres, because degeneration always occurs along the line of conduction, and we look upon the fibres of the direct cerebellar tract as prolongations of the cells of Clarke's column upwards (see fig. 7). If then, the cells of Clarke's column be proved to be connected with the visceral fibres, impulses are conveyed through these from the visceral and vascular system to the cerebellum. Certainly injury of the post-vesicular column is associated with various visceral disturbances, as some of the cases enumerated show;

but disease of this column is also associated with a lesion of the postero-external column and ataxy. The following explanation has been offered by Dr Ferrier (*Functions of the Brain*, p. 216).

"It is a question whether, along with tactile or common sensory, visual or labyrinthine impressions, other sensory impressions are correlated in the cerebellum with the motor adjustments necessary for stability and equilibration;" and he suggests "that possibly visceral or organic sensory impressions are represented in the cerebellum, mainly on the ground of the very intimate mutual relation between states of the viscera and the exercise of equilibration." For example, in sea-sickness.

In connection with these speculations by so great an authority, it is permissible to follow his suggestion that the direct cerebellar tract may form the afferent path between the viscera and cerebellum, also may at the same time contain fibres which transmit the impulses in connection with equilibration and the erect posture in Man. If this hypothesis be tenable it is possible to fit in the facts previously discussed in the paper. The two forms of cells—the large multipolar ones which are seen so distinctly in Man in the lower dorsal and upper lumbar region—may be assumed to be connected above with fibres going to the cerebellum, and to transmit impulses which serve for equilibration in the erect posture. Certainly the distribution of the cells in Man, as compared with the Monkey and Dog, would suggest their connection in some way with the erect posture. The fusiform cells which are found throughout the column are, as a rule, smaller, and more like those of the vagal nucleus, being more particularly connected with the visceral fibres. If it be true that large cells are connected with large fibres, and small cells with small fibres, only the small cells can be associated with the small medullated fibres described by Gaskell.

Upon examination of the micro-photo, fig. 3, it will be seen that in the postero-external column the fibres are of unequal size, varying from 5μ to 10μ. We might then consider these smaller fibres to be associated with the smaller cells, and the larger with the larger cells.

In connection with Bechterew's researches, I may say that I have in many sections seen fibres passing from Clarke's column forwards to the anterior horns. If these were sufficiently constant, we might believe that these fibres passed out as efferent

medullated fibres, possibly the small fibres of Gaskell. At present histological researches in normal and pathological specimens of the cord only definitely prove two sets of fibres in connection with Clarke's column. These are the inner set of fibres of the posterior root, which pass into the root-zone of the postero-external column, thus forming the lower segmental set of fibres, the nutrient ganglia of which are in the spinal ganglion of the posterior root; and a second set of fibres, which issue from the cells of Clarke's column, passing outwards to the periphery, and then forming the direct cerebellar tract.

Literature.—Gaskell, "Nerves of the Visceral and Vascular System," *Journal of Physiology*, vol. vii., No. 1; Ross, *Diseases of Nervous System*; Schwalbe, Hoffman's *Anatomie des Menschen*; Henle, *Handbuch der Anatomie*; Lockhart Clarke, *Philosophical Transactions*, pp. 51–53; Gower's *Diseases of Nervous System*, vol. i.; Ferrier, *Functions of Brain*; Hughes Bennett, *Clinical Transactions*, 1885; Krauss, *Neurologisches Centralblatt*, 1885; Lissauer, *Archiv für Psychiatrie und Nervenkrankheiten*, 1885; Bechterew, "Uber den Nervenwurzeln," *Archiv für Anatomie*, 1887.

NOTE ON THE ACTION OF THE URETERS AS OBSERVED DURING AN OPERATION FOR THE REMOVAL OF AN ABDOMINAL TUMOUR. By J. Greig Smith, M.A., F.R.S.E., Surgeon to the Bristol Royal Infirmary.

THE tumour, a large ovarian cystoma (58½ lbs.), with very numerous septa, had pushed the intestines with the mesentery upwards in front of it, and the main bulk of the growth lay in the upper abdomen, greatly expanding the lower ribs. The growth was universally and densely adherent, and a long incision was necessary. When the tumour was removed and the pedicle secured, some time had to be spent in checking bleeding high up in the cavity. During this time my attention was attracted to the ureters, which were clearly visible during their whole length from kidney to bladder. The intestines were well out of the way, under the liver, and there was positively nothing between the anterior and posterior parietes as high up as the kidneys.

A small knob seemed to arise at the top of the right ureter and rapidly to descend to the bladder. Very soon a similar knob appeared on the left ureter and descended in the same way. When I again observed their action it was synchronous; and during at least three subsequent ureteric contractions the action was nearly synchronous. In a little while I observed that one ureter had got ahead of the other, and when I finally noted the phenomenon the ureters were acting alternately.

These observations were superficially made during the progress of a serious operation, when little attention could be paid to them. But the subject had a certain fascination, and I noted down, immediately after the operation, as well as I could, my impressions of the time occupied in each complete ureteric contractile act, and of the period which elapsed between the time when their action was synchronous and alternating. As nearly as I could estimate it I judged that the globe of fluid traversed the whole length of the ureter during one respiratory act of the patient—say four seconds. It was rapid, surprisingly so; and looking back upon it, and comparing its rapidity as it appeared then with the impression it has left upon my mind, I cannot believe that it occupied more than five seconds, certainly not six. I had tied two vessels, removed one sponge and replaced it by another, before I observed that the contractions of the ureters were alternating, and this time I should roughly estimate at three minutes.

In Landois and Stirling's *Physiology* (p. 649) I find that, according to Mulder's observations, several drops of urine pass into the bladder every three-quarters of a minute, and that the contraction passes along the tube at the rate of 20 to 30 mm. per second. Lauder Brunton (quoting Engelmann), in his *Pharmacology* (p. 113), says that

the excitability of the ureter being diminished during exhaustion or artificial respiration, " the effect of minimum distension in increasing its rhythm becomes very evident." During my observation the patient, very weak and ill before operation, was, near the end of the operation, in a very exhausted state; and there was absolutely no pressure on the ureters beyond that of the atmosphere. It should be noted further, that before operation the ureters must have suffered compression considerably in excess of the normal. During the first twenty-four hours after operation the patient passed 28 ounces of urine, a quantity slightly in excess of the average as noted in other similar operations.

NOTE ON A METHOD OF PRESERVING BLOOD-CORPUSCLES FOR MICROSCOPICAL EXAMINATION. By Mr RANDLE LEIGH, *Holt Tutorial Scholar in Physiology, University College, Liverpool.*

THE following method of preparing permanent microscopical specimens of blood-corpuscles is extremely simple, and in my hands has yielded very satisfactory results. A thin film of blood on a cover-glass is gently dried, and inverted, for half an hour or more, into a covered capsule containing a half-saturated solution of safranin in absolute alcohol.

The loosely adhering stain is then washed off by a stream of distilled water, after which it is again thoroughly dried, and mounted either in Canada balsam, liquefied by heat, or thinned by turpentine.

With human blood the corpuscles are stained a beautiful clear pink colour; and in non-mammalian blood the nuclei are stained dark pink, while the rest of the red corpuscles is lightly tinged. The specimens which I made three months ago have retained their colour perfectly.

Notice of New Book.

Mémoires sur le Cerveau de l'Homme et des Primates. Par Paul Broca, publiés avec une introduction et des notes par le docteur S. Pozzi Paris, 1888.

Dr Pozzi has done good service to anatomical science by collecting and publishing, in a convenient-sized volume, the several memoirs on the brain of Man and Apes written by the late Professor Paul Broca. The volume opens most appropriately with the series of memoirs on the *Siège de la faculté du langage articulé,* the first of which was published in 1861, and which at once won for its author a world-wide reputation as an acute observer and thinker. These are followed by a number of short essays on the pathological anatomy of the brain. But about two-thirds of the work is occupied with the several memoirs which he wrote on the comparative anatomy of the organ. The most important of these are the essays on the brain of the Gorilla, on cranio-cerebral topography, on cerebral nomenclature, and on the great limbic lobe in the brains of mammals generally.

We have no intention of entering into a criticism of Broca's writings on the comparative anatomy of the brain. It may suffice to state that they show a wide range of observation, and that in the elaborate essay on the great limbic lobe the homology of that lobe and of the convolutions in other parts of the mantle of the hemisphere s discussed with great acumen, though we are not prepared to accept all the conclusions to which the author has arrived.

PROCEEDINGS OF THE
ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

An Ordinary Meeting of the Anatomical Society of Great Britain and Ireland was held on Wednesday, February 8, at King's College—Professor Humphry, F.R.S., President, in the chair. Present—Thirty members and visitors.

Mr Mayo Collier read his paper on *The Functions of the Sinuses of Valsalva and Auricular Appendices, with some Remarks on the Mechanism of the Heart and Pulse.*

(Abstract.)

The object of the paper is to disprove the present apparently accepted idea, that the sinuses of Valsalva are mere bulgings of the arterial walls, formed by a reflex current induced by the sudden closure of the semilunar valves.

The existence of a reflex current is shown to be impossible, and the theory of the sudden opening and closure of the semilunar valves is strongly opposed.

The presence of the sinuses of Valsalva is urged as an absolute essential to the mechanism of the heart's action. The paper then treats of the action of the auricle and the part played by the auricular appendix, the latter being considered as the only part of the auricle that sensibly and vigorously contracts.

The causes of the first sound of the heart are next alluded to, and the theory that the closure and vibration of the tricuspid and mitral valves assist in its production is refuted. The action of the ventricle and the mode of the injection of its contents into the aorta is dwelt upon at some length.

The latter part of the paper is devoted to the mechanism of the pulse, and an explanation is given of the so-called dicrotism.

The paper terminates with a summary of the chief points of the conclusions arrived at.

Ossification of Skull.—Mr J. Bland Sutton showed specimens of the ossification of the superior maxilla, inferior maxilla, and malar bones to illustrate his paper on the morphology of the skull (*Proc.*, p. 3, Oct. 1887).

Mr Sutton claimed that the superior maxilla and inferior maxilla showed the centres he had mentioned in his paper, but the malar bone was not entirely satisfactory.

There was no discussion.

Cranio-Cerebral Topography.—Professor Cunningham, of Trinity College, Dublin, showed a series of models illustrative of the relations of the different parts of the brain to the surface of the head at dif-

d

ferent periods of life. He stated that the results of his investigation would shortly be published in the *Transactions of the Royal Irish Academy*, but that in the meantime he desired to explain the methods he had adopted in the preparation of the models. As the work progressed he had been able to improve greatly upon the methods he had at first employed, so that latterly he had been able to harden the brain *in situ*, and obtain a cast which gave absolutely accurate results in every detail.

The methods were the following :—(1) A careful cast was taken of the entire head immediately after the subject came into the anatomical department. This was laid aside, and means were then taken to harden the brain. (2) Injection pipes were placed in the internal carotid arteries, and twice daily the head was injected with the following fluid :—1 part spirit (60 over proof); 2 parts Müller's fluid. To each injection 4 drachms of glycerine were added. This treatment was continued for a fortnight. (3) When the injections had been fairly started the scalp was removed from the right side of the head, and the whole preparation immersed in 15 per cent. solution of hydrochloric acid. The action of the acid was carefully watched until the outer table and *no more* of the cranial wall was softened. (4) The head was then taken out of the acid solution and washed in water and fixed in a vice. The whole of the cranial wall on the right side, with the exception of narrow bars corresponding to the sutural lines, was next removed. The utmost care was taken to preserve the dura mater intact, because it was found that so long as this was entire the injections could be continued, and the brain kept from shrinking. (5) When it was considered that the brain was sufficiently hard, a 10 per cent. solution of hydrate of chloral was substituted for the Müller and spirit injection, and after three applications of this the membranes were removed and the cast taken. (6) Immediately before the removal of the membranes the specimen received the last injection. By doing this it was found that the brain would retain its full size, and not undergo the least shrinkage for at least twenty-four hours. Each cast required a mould of from thirteen to fifteen pieces, and these could generally be made in about five hours. (7) When the cast was drawn from the mould an attempt was made to depict the brain on ˙the outside of the corresponding cast of the untouched head. Great difficulty was here experienced, because the surface upon which it had to be drawn was of course considerably wider in its area than the surface of the brain. The suture lines and the brain fissures were, however, accurately adjusted, and the defects in the representation therefore are to be found chiefly in the greater breadth of the convolutions and size of the lobes generally.

The series of models exhibited comprised the following :—

1. Head of a boy of five years old.
2. Head of a girl of 11 years old.
3. Head of a boy of 12 years old.
4. Head of a youth of 15.
5. Head of an adult female.
6. Head of an adult male.

Two casts of the entire head with the brain depicted on the outside (corresponding to Nos. 2 and 3) were also shown.

Professor CUNNINGHAM then read a paper on the *Musculus sternalis*,

which paper is printed *in extenso* in the *Journal of Anatomy and Physiology*, vol. xxii. (N.S. vol. ii.), p. 391.

In this paper is detailed the nerve-relationships of seventeen cases of the musculus sternalis. From these the following conclusions are drawn :—

1. That the sternalis muscle is a portion of the pectoralis major.

2. That it is produced by a rotatory dislocation of certain of the fibres of the great pectoral.

3. That different fibres are used for this purpose in different cases.

4. That the deviation of the fibres of the great pectoral restore in this portion of it the primitive direction and primitive connections of the pectoral muscle.

5. That the anomaly may possibly be regarded as showing a tendency to the formation of a new muscle in man devoted to costal inspiration.

Professor HUMPHRY considered the existence of the sternalis due to incomplete segmentation of the great muscular sheet

Professor MACALISTER discussed the question of the origin of the sternalis, and thought too much stress had been laid upon the last point. The muscle was present in 3 cases out of 115, but this was a low average. He confirmed Professor Cunningham's observations that the muscle was absent in other mammals.

Professor THANE was inclined to agree with the author of the paper. He discussed the question whether the muscle was vestigial or developing, and, in the latter case, as Professor Cunningham had remarked, devoted to costal respiration.

Mr SUTTON also made some remarks.

Professor CUNNINGHAM then communicated for the author the following paper on the *Morphology of the Muscles on the Extensor Aspect of the Middle and Distal Segments of the Limbs*, by H. ST JOHN BROOKS, M.D.

In this paper the muscles on the extensor aspect of the fore-arm and hand, and the corresponding group of muscles in the leg and foot are referred to a type schema which is constructed as follows :—
The mass of muscle on the extensor aspect of the upper segment of the limb is inserted in part into the bones of the middle segment (forming the triceps or quadriceps), and in part prolonged below the elbow or knee. Here it divides longitudinally into three sectors—a radial or tibial, an ulnar or fibular, and an intermediate. The two marginal sectors are each in part inserted into the bones of the middle segment (anconeus and supinator brevis in man). The intermediate sector divides into three slips, which are inserted into the three middle metacarpal (or metatarsal) bones. The radial sector is inserted into the first metacarpal bone, the ulnar sector into the fifth. Thus each of the five metatarsal (or metacarpal) bones has its own long extensor, and from each tendon of insertion a fascial slip is sent forward to join the tendons of the short extensor. The short or deep extensor is composed of five muscular slips which end in as many tendons ; these tendons are inserted into the phalanges of the five

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digits. This extensor brevis radiates from the centre of the carpus (or tarsus) and each slip is reinforced by a pair of accessory heads which arise from the corresponding metacarpal (or metatarsal) bone. These accessory heads are not dorsal interossei ; they are supplied by the posterior interosseous (or anterior tibial) nerve, and are represented by well-developed muscles in reptiles, and by the occasional extensor brevis digitorum manus, and by the deep slips of extensor brevis digitorum pedis (described by Ruge) in man.

Hatteria may be selected as an animal which departs but little from the above type, and at the same time such deviations as occur are probably among the first to take place in vertebrate animals above Pisces and foreshadow the more profound modifications which have come to pass in the higher Mammalia. The most important deviations from the type in this lizard are—(1) the segmentation of the muscles on the extensor aspect of the fore-arm and leg from the muscles of the arm and thigh ; (2) the attachment of the extensors of the carpus and metacarpus to the radial condyle of the humerus, and the origin of the corresponding muscles in the hind limb from the tibia and fibula (with the exception of the intermediate sector, which is attached to the *fibular* condyle of the femur); (3) the partial segmentation of the ulnar sector into anconeus and extensor carpi ulnaris, and of the radial sector into extensor carpi radialis and supinator longus brevis ; also the absence of any insertion of the tibial and fibular sectors into the tibia and fibula (such an insertion, however, exists in the *Cryptobranchus,* as Professor Humphry has shown (*Jour. of Anat, and Phys.,* vol. vi. p. 41) ; (4) the development from the extensor brevis digitorum of an extensor ossis metacarpi pollicis (or metatarsi hallucis), which, in company with the more radially (tibially) placed bellies of the extensor brevis digitorum, has wandered from the dorsum of the hand (foot) to a more proximal point on the fore-arm (or leg).

A great deal of the above work has already been done by Professor Humphry, but a general restatement of the morphology of these groups of muscles appears desirable. The following points do not appear to have been distinctly indicated in any previous paper:—(1) That the extensor minimi digiti of human anatomy was originally the fifth belly of a deep (short) extensor ; (2) that the anconeus belongs more properly to the extensor carpi ulnaris than to the triceps ; (3) that the occasional extensor brevis digitorum manus in man is not homologous to the extensor brevis digitorum (pedis), but to the occasional deeper slips of the latter muscle (as described by Ruge) and to the metacarpal (metatarsal) heads of the short extensor in reptiles (so often confounded with interossei dorsales); (4) that the condition of the extensor brevis digitorum in Man is a reversion to type, from which type the same muscle has wandered in Ornithorhynchus and marsupials (the latter condition is considered to be the primitive by Ruge); (5) that the "nerve to the anconeus" of human anatomy is homologous to the branch of the anterior crural described by Ruge in Ornithorhynchus (*Morph. Jahrbuch,* Bd. iv., 1878, p. 597), which is distributed to the tibialis anticus and extensor hallucis longus, being *a nerve from the trunk which supplies*

the extensor of the middle segment prolonged to the extensors situated below the knee (or elbow) joints.

Vestigial Muscles.—Mr J. BLAND SUTTON then read a paper, part of which, he said, was directly opposed to the views advanced by Dr St. John Brooks. In this paper an endeavour is made to show that Man, in common with the Quadrumana, originally possessed a complete deep, as well as a superficial, set of extensors for the fingers. This deep set primitively arose from the extensor condyle of the humerus, and adjacent parts of the olecranon. Gradually they migrated down the ulna. The secundus descended first, then the indicis; the medius and annularis gradually followed, but the extensor minimus retained its old connection with the condyle. As the muscles descended, they carried with them a branch of the musculo-spiral nerve—the posterior interosseous. By degrees the medius and annularis regressed into fibrous tissue, and the nerve became embedded in their remains on the back of the carpus.

An attempt was also made to show that Gimbernat's ligament and the triangular fascia are persistent remains of the ligament which binds the epipubes to the ilio-pectineal line in the marsupials. Finally, reasons were advanced for regarding the ilio-femoral band of the human hip-joint as the fibrous representative of the gluteus quartus, a muscle extremely common in all classes of mammals and often functionally present in Man.

Obliteration of Cœliac Axis.—Professor THANE exhibited a specimen in which the cœliac axis was obliterated, and the collateral circulation established through the pancreatico-duodenal arteries. The arrangement of the vessels is shown in the accompanying figure, in which

the renal and spermatic arteries are omitted for the sake of clearness. The cœliac axis was represented at its origin from the aorta by an impervious fibrous cord, 2·5 mm. thick and 11 mm. long. This was succeeded by a sinus-like dilatation, from which the left phrenic, the

coronary, the splenic, and the hepatic arteries were given off. The hepatic artery was of large size, having a diameter of 9 mm.; the calibre of the others was normal. The hepatic artery, having given off the small pyloric branch, divided into an ascending portion to the liver (6 mm.), and a larger descending part, the gastro-duodenal artery (8 mm.). The latter was continued, after supplying the right gastro-epiploic artery, into the greatly enlarged superior pancreatico-duodenal (7 mm.).

The superior mesenteric artery was larger than usual (9 mm.), and divided after a short course into two parts of nearly equal size (7-8 mm.). The anterior of these was the normal trunk and furnished the usual branches. The posterior gave off the first intestinal branch to the beginning of the jejunum, and then turning to the right took the course of the inferior pancreatico-duodenal artery between the pancreas and duodenum. The superior and inferior pancreatico-duodenal arteries formed two large loops in the concavity of the duodenum, the vessels composing which had a diameter of 6 mm. and 4 mm. respectively, and were very tortuous with spiral windings. From the inferior pancreatico-duodenal artery a third large branch (marked *), 6 mm. in diameter, proceeded to the back of the second portion of the duodenum; but it could not be followed farther owing to the vessel having burst during the injection of the body. The branches of the cœliac axis were fed entirely through the loops formed by the pancreatico-duodenal arteries.

There was no appearance of disease in any of the vessels concerned, and no reason was suggested for the occlusion of the cœliac trunk.

Professor CURNOW showed the following specimens :—
(1) An inter-parietal bone. (2) A constricted aorta, with enlarged anastomotic branches. The constriction, which amounted almost to obliteration, occurred at the junction of the arch with the trunk of the thoracic aorta immediately below the attachment of the ductus arteriosus. The internal mammary arteries were much enlarged as well as the superior intercostals, which were seen to be freely inosculating with the enlarged first aortic intercostals on both sides. The other aortic intercostals were evidently larger than normal. (3) A double aortic arch enclosing trachea and œsophagus (*Trans. Path. Soc. Lond.*, vol. xxvi. p. 33). The trachea and gullet (which is in its ordinary position behind and to the left) are encircled by a pervious vascular ring formed in front by a left brachio-cephalic trunk, the first part of the left subclavian, and the communicating vessel between it and the descending aorta, and behind by a posterior aortic arch, from which the right carotid and subclavian arteries take origin.

Specimens.—The following specimen was also shown :—
Mr KENNY : Abnormal relation of phrenic nerve to the subclavian vessels.

It was then announced that the next meeting would be held at St Bartholomew's Hospital, on April 18, at 4.45 P.M.

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STURNELLA M. NEGLECTA (× 2).

ICTERIDÆ AND CORVIDÆ.

THE ANATOMY OF THE PAPILLA FOLIATA OF THE HUMAN INFANT. By FREDERICK TUCKERMAN, M.D., B.Sc., *Amherst, Massachusetts.* (PLATE XVIII.)

TASTE-BULBS have long been recognised in the folds or fringe of mucous membrane situated upon the lateral margins of the mammalian tongue, just in front of the anterior pillar of the fauces. They were first discovered in this region in the rabbit and hare, and later researches have shown them to be normally present on this part of the tongue in man, the horse, dog, pig, squirrel, rat, guinea-pig, mouse, bat, and some marsupials.

Of the animals just enumerated, those belonging to the order *Rodentia* usually have a well-developed papilla foliata. In man and the pig this organ varies much in appearance, and is generally more or less rudimentary in structure. In other animals, including some of those already mentioned, there exists in place of this organ a fringe of papillæ, which may or may not bear taste-bulbs. In the cat this fringe is particularly well marked. It consists of five to nine elongated and rather coarse cone-shaped papillæ, placed in a single row, and having their apices directed outwards. Sparingly scattered about the base of these papillæ are a few glands of the serous type. An examination of many sections of this fringe, from the tongue of the new-born kitten and full-grown cat, failed to reveal the presence of gustatory structures, though they occur in the epithelium of the neighbouring fungiform papillæ.

The papillæ foliatæ, or gustatory lamellæ of Turner, of the human tongue, offer an excellent area in which to study the taste-bulbs. They consist of five to eight irregular folds or

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[1] Introduction to *Human Anatomy*, 1875, p. 380.

ridges,[1] with rounded or flattened crests, separated from each other by furrows which vary much in breadth and depth. Occasionally the bottom of a furrow is invaginated upwards into a ridge (fig., *F".*) which usually bears a few taste-bulbs. Serous glands and ducts are very plentiful in the sub-mucous tissue underlying the folds, and are also frequently present within them. The ducts are oftentimes quite straight, sometimes winding, and occasionally of considerable length. They generally open between the folds, either at the sides or bottom of the furrows. I have seen in vertical sections as many as five separate ducts opening into a single furrow.

Each fold consists of one or more papillary upgrowths of the mucous membrane, the exposed surfaces of which are everywhere invested with a layer of epithelium of varying thickness.[2] Not unfrequently two, but more commonly three, papillary upgrowths of the mucous membrane are present, the depressions between them being filled largely with elongated, spindle-shaped, epithelial cells, nearly or quite to the level of the top of the fold.

The taste-bulbs of this gustatory area are a trifle smaller, generally speaking, than those of the circumvallate papilla. Their average length is about 0·075 mm., and their greatest transverse diameter 0·0375 mm. They are disposed at the sides of the folds (though frequently occurring on the summit) in several tiers. It is quite impossible to state, with any degree of accuracy, the exact number of tiers, owing to the lack of uniformity in the distribution of the bulbs. Very often they are present only upon one side of the furrow, and occasionally entire folds will be destitute of them. As seen in vertical section, the bulbs are separated from each other by an interval about equal to their transverse diameter. In horizontal section, however, they are placed much nearer together, and quite often are in contact by their edges. Frequently, in the interbulbous spaces, the faint outline of a bulb can be made out, suggesting

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[1] In fœtuses of four and one-half and five months, I was unable to distinguish any lateral folds on the tongue. 1 had no opportunity of examining a fœtus of the sixth month, but in two of the seventh the folds were very clearly defined.

[2] The average thickness of the epithelial covering of the sides and upper surface of the folds, when destitute of taste-bulbs, is about 0·05 mm.; when there are bulbs present, it is, of course, thicker.

an alternate arrangement of the tiers. In a single instance a bulb was detected pushing its way up from the sub-epithelial tissue, between two adjacent ones, but not in contact with them. The basal end and lower third of this bulb rest in a cavity of the mucosa, and its apex penetrates the deeper layers of the epithelium. I estimated the number of bulbs in each lateral papilla at about 1500. This calculation was made from the papilla foliata of an infant four months old.

The bulbs vary considerably in size, shape, and general appearance, but most of them possess a well-defined neck, which sometimes projects for a short distance beyond the outer homogeneous layer of epithelium. In a few bulbs the outer extremity of the cover-cells had separated. It is possible that this appearance of the apex of a bulb has been mistaken by some observers for the peripheral processes of the taste-cells protruding through the free opening.

Non-medullated nerve fibres enter the bases of the folds, and their terminal branches ran towards the sides containing the taste-bulbs. Farther than this I was unable to trace them.

EXPLANATION OF PLATE XVIII.

Upper Figure. Transverse vertical section through papilla foliata of an infant four months old. *Fd.*, folds; *S.R.*, secondary ridges; *Ep.*, epithelium; *F.*, furrow; *F'.*, invaginated furrow; *T.B.*, taste-bulbs; *S.D.*, serous ducts; *Mm.*, mucous membrane. × 18.

ERRATA in Author's Paper on *Fiber zibethicus*, January 1888.

Page 135, line 7, *for* colloidin, *read* celloidin.
„ 136, „ 15, *for* exists, *read* rests.
„ 138, „ 19, *for* gland, *read* band.

THE EPIPHYSIS CEREBRI IN *PETROMYZON FLUVI-ATILIS.* By James R. Whitwell, M.B. (Edin.), *Pathologist to the South Yorkshire Asylum, Sheffield.* (Plate XVIII.)

The pineal gland has of late years received a large amount of attention, more especially on account of the recent observations of De Graaf[1] and Baldwin Spencer,[2] by which it appears probable that the so-called pineal "gland" represents a rudiment of an eye, which possibly was functional in the case of certain extinct amphibia and saurians.

In the course of an examination of the nervous system of the Lamprey (*Petromyzon fluviatilis*), the pineal eye was an exceedingly noticeable feature. This organ, however, has been examined by Ahlborn;[3] but in the cases which I have examined, the arrangement and structure is apparently somewhat different from his description, and accords more with the pineal eye described by Baldwin Spencer in certain *Lacertilia.*

A most striking point on external examination of the dorsal surface of the Lamprey is a whitish perfectly transparent spot, lying in the same transverse plane as the eye, and some little distance posterior to the external aperture of the olfactory fossa. On looking through this, on to the brain lying beneath, a minute black spot is discernible, lying usually slightly eccentric. On making a section of the fresh skull in this region (by the freezing method of Dr Bevan Lewis), it is seen that the fibro-cartilaginous skull has at this point undergone changes which considerably alter its reaction to light, it has become translucent, and has a hyaline appearance, and the branching pigment-cells, so marked a feature elsewhere, have here disappeared. In fact, the alterations are such as to readily suggest the analogy of the cornea.

On examining the structures immediately subjacent to this

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[1] *Zoolog. Anzeiger*, March 1886.

[2] *Quart. Journ. Mic. Sci.*, Oct. 1886.

[3] "Untersuchungen über das Gehirn der Petromyzon," *Zeit. f. Wiss. Zool.,* 1883, quoted by Spencer.

cornea-like space, there are seen to be two small vesicles, lying one on the top of the other, their presence being rendered noticeable on account of the extensive pigmentation which the cells composing them have undergone. The upper vesicle is seen to be formed of a continuous line of somewhat columnar cells, the cells of the lower layer being considerably longer than those of the upper. The former are deeply pigmented towards the side corresponding to the cavity of the vesicle, their external ends usually showing nuclei, and scattered about among the cells at this end are a few spherical pigmented masses; more external still to this is a fibrous layer. The upper wall of this vesicle is also composed of somewhat columnar cells, but these are never apparently so long as those forming the lower wall, and these cells are rarely pigmented. The whole of the upper vesicle is slightly curved on itself, so as to have a slightly concave upper surface presented to the transparent cornea-like roof of the skull. But in no case is anything comparable to a lens discoverable. Within the vesicle is a small quantity of a material, partly composed of fine filaments, which stain lightly with aniline blue-black, and which are usually arranged so as to pass between the upper and lower walls of the vesicle. The lower of the two vesicles lies immediately beneath the upper one, and is usually somewhat pyriform in shape, with its base looking anteriorly towards the olfactory region; it also is seen to be lined by columnar epithelium, the cells of which become smaller as the caudate portion of the vesicle is reached, and many of the cells are pigmented; its cavity is empty. From the caudiform end of this cavity a process is seen to extend, which is apparently fibrous in structure, but which is doubtfully composed of nervous elements. This process is the pineal "stalk," and, as is well known, extends downwards and backwards to the roof of the thalamencephalon. The pia mater becomes continuous with the upper part of this stalk, and thus the pia mater is attached to the "eye." The dura mater also forms a capsule for it.

The possible significance of this arrangement and structure of the pineal "gland" has been thoroughly examined by Baldwin Spencer in connection with certain Lacertilia, and it appears that this structure in the Lamprey is sufficiently in accordance

with his researches to warrant its being classed as another argument in favour of his view. One of the chief difficulties associated with the pineal " eye " is its apparently invertebrate type, in that the nerve enters into connection with the external lying elements, and the rods appear to face into the cavity of the vesicle, according to Baldwin Spencer's view, though, again, the difference in the formation of the possible lens of the pineal eye in Lacertilia, compared with the development of the same structure in invertebrates, appears to negative this view. Possibly, however, it may be that, in the case of the pineal eye, there is an arrest in the development of the vertebrate eye of the usual type, and this arrest occurs at the " secondary optic vesicle " stage, and that the cells of the proximal layer of this developmental vesicle corresponds to the proximal layer of the pineal eye. The normal evolution of this proximal layer in the development of the functional eye is to form the pigmented layer of the retina, which, in the pineal eye, has occurred while the normal evolution of the distal layer lies in the formation of the nervous tissue proper of the retina, which stage the pineal eye does not reach, as far as is known, in any living animal, though, in the case of *Varanus giganteus* and *Hatteria punctata*, this layer has become developed into elongated columnar nucleated cells, as has been so clearly shown by Baldwin Spencer (forming his lens). By this view, then, the pineal eye in these cases would be considered as a phylogenetic representative of a developmental stage in the vertebrate eye, rather than an imperfect approach to the invertebrate type.

EXPLANATION OF PLATE XVIII.

Fig. 1. Vertical longitudinal section through skull and brain of Lamprey under low power, the pineal eye lying close beneath the skull, its upper vesicle, with lower thick layer of cells pigmented deeply at inner ends—its relation to pia mater (*P.M.*). Lower vesicle pyriform, with stalk forming behind prosencephalon, portion of which is seen (*Pros*). *Olf.*, posterior part of olfactory capsule.

Fig. 2. Transverse section of fresh skull, &c., showing pineal eye enclosed in a layer of dura mater (*D.M.*). *Co.*, clear hyaline cornea-like space in roof of skull. Pigment cells (*pig.*) are absent from this part of skull. *Uv.*, upper vesicle. *Lv.*, lower vesicle.

DEVELOPMENT AND TRANSITION OF THE TESTIS, NORMAL AND ABNORMAL. By C. B. LOCKWOOD, F.R.C.S., *Hunterian Professor, Royal College of Surgeons, England.*

(Continued from p. 478.)

LECTURE III.—*continued.*

IF the observations recorded in the earlier part (p. 464) of this Lecture be correct, the testicle has attained its position upon the brim of the pelvis, and almost in contact with the hypogastric arteries and the abdominal walls, by a gradual process of development and growth. But already, at the third month, preparations are being made for the active transition of the gland through the abdominal wall, and its final deposition in the scrotum. Amongst these preparations are comprised the further development of the mesorchium and of its ascending and descending processes, namely, the plica vascularis and the plica gubernatrix, the development of the gubernaculum itself, the development of the inguinal canal, and, finally, the development of the scrotum.

It is convenient to refer briefly to such of these as can be seen with the naked eye, and then proceed with those which require to be studied by means of histological sections.

The Mesorchium, Plica Gubernatrix, and Plica Vascularis.

The mesorchium has frequently been mentioned before, and is the fold of peritoneum which unites the mesonephros, and afterwards the epididymis, to the back of the abdomen; the word is not, perhaps, quite free from ambiguity, for the mesentery belongs more especially to the mesonephros, but as the name is established by custom, it is desirable to continue its use. At the third month the mesorchium is but a slender support, and is prolonged upwards from the epididymis in a small triangular fold; and, as this subsequently contains the spermatic vessels, I

have, in a paper on " Encysted and Infantile Hernia," [1] ventured
to call it the plica vascularis. Without doubt the plica vascu-
laris is the same as the fold which at an early age unites the
upper end of the Wolffian body to the diaphragm, and is
called by Kölliker [2] the diaphragmatic ligament of the meso-
nephros (Zwerchfellsband der Urniere). However, in the later
stages these relations of this fold are quite subordinate;
whilst, as will be seen, its relations to the spermatic vessels
are of practical and pathological importance. The mesorchium
is shown in the accompanying drawing, made from a human
embryo of the third month, and in this specimen the testicle and
kidney are a little way apart, the separation being caused, I
believe, by the growth of the lumbar spine and pelvis, including
the sacrum in the pelvis. The plica vascularis does not reach
quite as far as the kidney, but is, nevertheless, an obvious feature
(Pl. XVII. fig. 48). The lower part of the mesorchium is, on
either side, continued along the right and left genital strings, to
become continuous with a cord which passes down to the outer
side of the hypogastric arteries, and ends in the abdominal
wall. This cord is an early stage of the gubernaculum testis,
and the downward prolongation of the mesorchium [3] is the
plica gubernatrix. It is hardly requisite, perhaps, to trace
minutely the gradual growth of the mesorchium. It does not,
perhaps, develop luxuriantly in every fœtus, but at about the
end of the seventh month it usually has the appearance seen in
the accompanying sketch (fig. 49). The base of the mesorchium
was loosely fastened along the psoas muscle, and its free edge
ended upon the epididymis and testicle; its lower fold contains
the gubernaculum, and the upper the spermatic vessels. How-
ever, at this age (seventh month) the chief interest of the upper
process centres in its relation, on the right side, to the cæcum,
vermiform appendix, ilium, and mesentery, to which it is now
(towards the end of intrauterine life) adherent; and later it will
be seen that this may have an important bearing upon the
pathology of congenital cœcocele; on the left side it passes

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[1] " The Morbid Anatomy and Pathology of Encysted and Infantile Hernia,"
by C. B. Lockwood, Med. Chir. Trans., vol. lxix., 1886.
[2] Kölliker, Entwicklungsgeschichte, p. 959.
[3] The mesorchium is sometimes called " Seiler's fold."

upwards to the sigmoid flexure. The plica gubernatrix, more-over, disappears below in a peritoneal pouch, which is the beginning of the processus vaginalis. The formation of this

FIG. 49.[1]—Drawing made from a seven or eight months' fœtus to show the fold (plica vascularis) which connects the testis with the cæcum. T, testicles; E, epididymis; P, psoas; V, vas deferens; G, plica gubernatrix, disappear-ing into processus vaginalis; P.V, plica vascularis; C, cæcum; S, spermatic artery; I, ilium.

protrusion may be considered after the development of the scrotum and inguinal canal.

The Development of the Scrotum and Inguinal Canal, including the Ascending and Descending Cremaster.

It is proposed as far as possible to pursue this branch of the subject by means of histological sections. As far as can be ascertained, most of our knowledge of it has been learnt by dissection;[2] yet, although a great deal of information has been gained in this manner, nevertheless, the embryonic tissues are so delicate and hard to manipulate that there seems to be still room for further inquiry. This refers more particularly to the histology of the earlier stages, and I now propose to describe them as briefly as possible, using for the purpose human em-

[1] I am indebted to the Council of the Royal Medico-Chirurgical Society for per-mission to use this and another block.

[2] F. Bramann, in his "Beitrag zur Lehre von dem Descensus testiculorum und dem Gubernaculum Hunteri des Menschen," *Archiv für Anat. und Entwick.*, 1884, p. 310 *et seq.*, gives an exhaustive account of the literature of the subject, and his investigations will be mentioned again.

bryos, which may be supposed to have attained the seventh, tenth, twelfth, and twentieth weeks of intrauterine life.

At the seventh week the structure of the abdominal wall is very rudimentary, and it contains but a trace of muscle in its substance. Its exterior is covered with a layer of epiblast, whilst it is lined within by a clearly defined but tenuous membrane, which is the beginning of the peritoneum. Where the peritoneum lines the front abdominal wall there is no trace of subperitoneal areolar tissue, but towards the back and lower part of the abdomen that tissue is abundant, even at this early age. The main bulk of the abdominal wall is composed of ordinary mesoblastic tissue of considerable density, but towards the middle line a quantity of fine deeply stained fibres betoken the advent of the rectus abdominis. The appearances in this embryo seem to indicate that, so far as concerns the muscles of the trunk, the degree of their development is determined by their size more than by other considerations; and, in consequence, such muscles as the gluteus maximus, erector spinæ, and ilio-psoas are the furthest advanced. In this embryo, also, the pubic cartilages were still some distance apart, and the mesoblast of the abdominal wall continued over their surface into the perinæum, making a decided bulge on either side below the pubes, in the situation of the future scrotum or labia majora, as the case may be; for it has been repeatedly said that the genital mass of this embryo is in the indifferent stage. The scrotal mesoblast is exactly the same as that which forms the abdominal wall, with the exception that it cannot be said with any degree of confidence that there is any indication of the conversion of any part of it into muscle.

Before leaving this embryo, I may mention that the bladder and hypogastric arteries are of some size, and are closely related to the lower third of the wall of the abdomen, behind the developing rectus abdominis; their width, taken together, is considerable, and they make the middle part of the lower front wall of the abdomen look very solid and impervious.

In the human embryo of the tenth week of intrauterine life (fig. 40, Lect. II.) the development of the abdominal walls has made further progress. Not only the rectus abdominis, but also the external oblique and transversalis, are clearly marked. The

fibres of the various muscles are imbedded in embryonic connective tissue, which is most abundant beneath the cutaneous surface and almost absent where the peritoneum lines the transversalis and rectus muscles. The sections which divide the abdominal wall near the site of the future internal abdominal ring show that preparations have commenced which may be supposed to be capable of facilitating the transition of the testicle into the scrotum. Before proceeding to detail them, it may be desirable to indicate the point at which they are seen. As regards the cartilaginous skeleton, it is situated almost vertically above the outer margin of the thyroid foramen, and consequently just internal to the head of the femur. In the next place they are immediately above the inner side of the external iliac vein, which is very large, and external to the hypogastric arteries. As in the younger embryo, these vessels, together with the bladder, occupy a large part of the lower middle part of the abdominal wall. Therefore I am about to describe the abdominal wall at the point at which the internal abdominal ring afterwards appears. The abdominal wall has the following layers:—externally, of course, a cutaneous covering, which has beneath it a thick layer of undifferentiated mesoblastic tissue; next comes a thin and deeply staining lamella which merges above in muscular fibres, and, I take it, represents the external oblique; a third muscular layer forms the next stratum, and upon its inner surface the peritoneum is closely applied, except at a point which will be mentioned directly; the last muscular layer constitutes without doubt the internal oblique and transversalis. Of these various strata, the cutaneous one may be dismissed without further comment. The subcutaneous mesoblastic tissue, as in the younger embryo, extends over the pubes and is continuous with the scrotal eminence. Towards the inner side of the iliac vein, and in the position of the internal abdominal ring, the external oblique layer makes a decided bend into the subcutaneous mesoblastic tissue and towards the scrotum. The concavity of this projection, which, I believe, is an early stage of the external spermatic fascia, is thinly lined with a layer of muscular fibres derived from the succeeding layer; these represent the beginning of the descending portion of the cremaster muscle, and their hollow is filled

with embryonic connective tissue. Presently, ascending cre-
masteric fibres will be mentioned, which are derived from the
muscular fibres of the abdominal wall which are nearest to the
peritoneum and which ascend with the gubernaculum testis.

In this embryo, moreover, the inguinal canal has begun.
The muscular layer of the lower abdominal wall (*i.e.*, of the
internal oblique and transversalis) may be said to have below
three portions, namely, the descending cremasteric fibres, the
ascending cremasteric fibres, and a middle set which descend no
further than the point at which the previous two are given off.
In consequence, an interval is left in the situation of the in-
guinal canal which has the ascending and descending cremaster
for its front and back boundaries, and the middle fibres for its
roof. The contents of this rudimentary inguinal canal are a
quantity of embryonic connective tissue, and some gubernacular
fibres which will be mentioned directly.

The peritoneum has been said to be closely united to the
inner surface of the transversalis muscle, and I have now to add
that it has nothing which corresponds to the bulging of the
external spermatic fascia and cremaster. Its surface is quite
even, with the exception of a short process which runs upwards
from the abdominal wall to either genital string, and which is
the beginning of the plica gubernatrix. There is a leash of
fibres within the plica like those of areolar tissue, and these
fibres pass upwards to the genital string and to the peritoneum;
below they spread out and pass beneath the edge of the mus-
cular layer of the abdominal wall (internal oblique and
transversalis), and mingle with the walls of the projection formed
by the external spermatic fascia and cremaster. The muscular
fibres of the abdominal wall, which are nearest the peritoneum,
instead of terminating, as the others did, to form an inguinal
canal, are, as I have already said, continued into the base of the
plica gubernatrix, and will be mentioned again in speaking of
the structure of the gubernaculum testis.

Finally, the testicle itself lies upon the ilium, and a very little
way from the front abdominal wall. The peritoneum in the
neighbourhood of the testicles and of the back wall of the
abdomen has beneath it an abundance of loose embryonic
connective tissue.

Assuming that these observations and inferences are correct, it is clear that the scrotum, and some of its layers, is formed long before the transition of the testicle, and quite independently of that event. There is nothing new or novel in this, but it is interesting to record the earliest stages of the process. Carus's theory, that the testicle, in its descent, carried down its own investments from the abdominal wall, has been so abundantly falsified that it is quite unnecessary to argue that the foregoing is also antagonistic to the views of that authority.[1] This is a convenient point to mention that the hypogastric arteries seem to have an influence in determining the point in the abdominal wall at which the processus vaginalis begins to appear. It has been stated in an earlier part of this lecture that those vessels, together with the bladder, render the lower median part of the abdominal wall exceedingly thick and impervious; whilst the lower and external part is comparatively weak and unprotected. From this it follows that after the testicle and vas deferens have passed into the scrotum the ostium of the processus has the hypogastric artery upon its inner side, and it is only after that vessel has dwindled that the epigastric artery takes its place, and becomes the inner boundary of the ostium. Moreover, at first the vas deferens in its course to the migrated testicle turns round the hypogastric artery, and receives a small branch from it—the deferential artery.

The next embryo, that of the twelfth week, was, of course, much larger and better developed than that which has just been described. It was cut into a series of transverse sections, which confirmed the inferences drawn from the previous embryo, which, it may be remembered, was cut longitudinally. The testicle of this twelve-weeks' embryo has already been figured (fig. 33, Lect. II.), and lay upon the brim of the pelvis and very close to the abdominal wall and hypogastric arteries. The genital strings, right and left, were united to the lower part of the abdominal wall by the plica gubernatrix. This fold was narrower at either end than in its middle part, where it bulged somewhat. Its substance consisted of round and spindle-shaped cells; the latter had a

[1] Sappey, *Traité d'Anatomie Descriptive*, vol. iv. p. 581, 1874, adduces several cogent reasons against Carus's theory.

decided likeness to unstriped-muscle cells, and were continued into the substance of the abdominal wall, in the situation of the inguinal canal. Moreover, the muscular fibres, which have been called the ascending cremaster, entered the base of the plica gubernatrix, and were, without question, continued upwards beneath the peritoneum, which formed the plica, as far as the genital string, or, as it might now be called, the vas deferens. At the point at which the plica gubernatrix was continuous with the peritoneum of the abdominal wall there was no irregularity or trace of the processus vaginalis. Both the external spermatic fascia and the descending cremaster bulge towards the scrotum, which consisted of embryonic connective tissue, whose stellate cells were very clear and unmistakable, and without any admixture of muscular fibres except those which have just been mentioned. The two halves of the scrotum had almost united, although in the perinæum there was still a wide opening beween the urethra and the exterior.

The main difference, therefore, between this embryo of the twelfth week and that of the tenth, assuming that their ages have been rightly calculated, seems to consist in a greater development of the muscular constituents of the gubernaculum testis, and of a further fusion of the halves of the scrotum.

It has been said that the testicle of this twelve weeks' embryo was upon the brim of the pelvis and quite close to the abdominal wall, and this position, it will be perceived, is the same as that which the Wolffian body and genital mass or testicle occupied in embryos of the seventh and tenth weeks; moreover, it may be added that, allowing for the growth of surroundings, its position in relation to the acetabular portion of the pelvis is practically the same.

The next stage, in which the development of the scrotum, and of the coverings of the testicle, and of the inguinal canal were investigated by means of histological sections, was probably the fifth month. In this case the processus vaginalis and gubernaculum testis had, as will be presently described, definitely appeared ; but, before mentioning them, the scrotum and inguinal canal may be referred to. Perhaps it is to be regretted that there is such an interval between this and the previous embryos, but as development proceeds it becomes more and

more difficult to obtain a reliable series of histological sections, and practically it will be found that the hiatus is not likely to lead to erroneous conclusions.

The foetus from which the following conclusions were drawn was in all respects well formed, and had probably attained the fifth month of intrauterine life; its fingers and toes had fairly well-developed nails. Of course the sex was quite unmistakable, and the penis and scrotum were, so far as regards their naked-eye characters, clearly and definitely established. A series of longitudinal sections of the pelvic region, and of the abdomen below the umbilical cord, were prepared by the paraffin method, after the bones had been decalcified. In this, as in nearly all the other specimens, the stain used was picro-carmine.

The testicles lay in contact with the abdominal wall, just external to the hypogastric arteries, and apparently in front of the acetabular portion of the pelvis. But at this stage it is harder to determine this point, because, owing to the growth of the muscles and other tissues, the gland is separated some distance from any bony landmark. Moreover, the testicle has grown so little in comparison with its surroundings, that it has become quite subordinate.

As may have been inferred, the testicle is separated from the kidney by an interval of more than a quarter of an inch. It would be easy to imagine that this separation might be due to an actual locomotion of the testicle itself, but the foregoing observations show, I think, that the gland and its epididymis have still the same relation to the pelvis as their precursors, the Wolffian body and genital mass, had. The various parts of the pelvis, ilium, ischium, pubes, and sacrum have grown enormously, and also the lumbar spine. Indeed the latter has grown so much that the spinal medulla only reaches as far as a point which may be judged to be the junction of the sacrum with the lumbar spine.

However, in this foetus the preparations for the actual transition of the testicle through the abdominal wall have made considerable progress, and, as we shall see, the processus vaginalis and gubernaculum testis are definitely established. But before these are described, the structure of the scrotum may be mentioned.

The surface of the scrotum was covered with a layer of epithelium exceedingly like that which covers the cornea, and this likeness was heightened by the absence of papillæ. In other regions the deeper layers of the epidermis were decidedly irregular, and rudimentary papillæ could be discerned. Beneath the epidermis there was a dense layer of spindle-shaped nucleated cells, the unstriped muscle fibre cells of the dartos. The bulk of the scrotum consisted of ordinary embryonic connective tissue, but its irregular cells looked more fibrillar than in the embryo of twelve weeks. Imbedded in this tissue was a denser layer of fibres, prolonged downwards from the external oblique muscle; these looped towards the perinæum, where they became gradually fainter, and finally disappeared. This layer, it may be assumed, was a further stage of the external spermatic fascia. The superficial part of the muscular layer of the abdominal wall also sent numerous fibres into the scrotum, where they spread out, and seemed to terminate; these are the fibres which have been called the descending cremaster. In the vicinity of the pubic cartilage the muscular fibres made smaller loops, and are attached to that part of the skeleton.

It may be mentioned that as yet the fibres of the various skeletal muscles, although well developed, had no appearance of striation; except perhaps in the case of the gluteus maximus and other large muscles, in which it was in places faintly indicated, but of course the mode of preparation may have made the striations indistinct. The internal spermatic fascia is a covering of the testicle which has not been mentioned. But it is questionable whether the transversalis fascia, of which the tunic in question is a part, is itself definitely formed. As in the case of the younger embryos, the peritoneum is closely applied to the transversalis muscle, although there is, even in this position, a small quantity of tissue suitable for conversion into a fascial layer. However, even this can hardly be discerned in the neighbourhood of the processus vaginalis.

There is a striking difference in the amount of subperitoneal tissue at the front and back of the abdomen. As I have just said, there is hardly any in front, whilst behind it is exceedingly abundant, and loose in texture.

It is hardly necessary to point out that in almost every

particular the histology of this five months' embryo confirms and extends the conclusions drawn from those of the tenth and twelfth weeks. Nor is it necessary to add that the external spermatic fascia and the descending cremaster seem to have reached the scrotum by some process of growth and development, and not by any manner of traction.

Processus vaginalis.

It is so well known that a peritoneal pouch precedes the testicle into the scrotum, that without further premise, we may proceed to discuss the manner of its formation. Presently it will be seen that the processus vaginalis has attained a fair degree of development in the five months' foetus which has just been described, and without doubt it appears a little earlier in intrauterine life. Care has been taken to point out that there was no trace of it in the series of sections made from either the ten weeks' embryo or that of twelve. Unfortunately, I have been unsuccessful in preparing histological specimens from embryos of between the twelfth and twentieth weeks of intrauterine life. But in dissected specimens of embryos of an intermediate size and development, and which might be assumed to have reached the sixteenth week of intrauterine life, there was a dimple in the peritoneum at the lower end of the plica gubernatrix, and this doubtless was the early stage of the processus. This accords with Bramann's[1] observations, but Kölliker[2] says the processus begins at the third month, and Weil[3] at the end of the second.

Reverting to the foetus of the fifth month, I would direct attention, first of all, to the processus vaginalis at its opening into the abdomen. The first section which has been drawn (Pl. XVII. fig. 50) shows very clearly the lumen of the processus vaginalis and its relation to the abdominal wall. In front of it are fibres of the internal oblique and transversalis and of the external oblique muscles. The abdominal opening has not been divided at its widest part, and in sections a little further from the middle line the projecting lips seen in the drawing are absent,

[1] Ibid., p. 320.　　　　　　　　　　[2] Entwicklungsgeschichte, p. 994.

[3] Weil, "Ueber den descensus testiculorum," &c., Zeitschrift für Heilkunde, Bd. V., Prag. 1884, p. 226 et seq. See also footnote, p. 524.

and the aperture involves not less than half the circumference of the canal. The plica gubernatrix projects from the floor of the processus and half fills its lumen; traced upwards it passes through the os tincæ and unites with the epididymis, but before doing so receives muscular fibres, the ascending cremaster, from the innermost layer of the abdominal muscles. The testicle lies quite close to the exterior of the processus vaginalis, and is at least twice the size of that aperture. If next the lumen the processus vaginalis be traced in its course through the abdominal walls it is found to diminish gradually (fig. 51), and end in the midst of the muscular fibres of the internal oblique and trans-
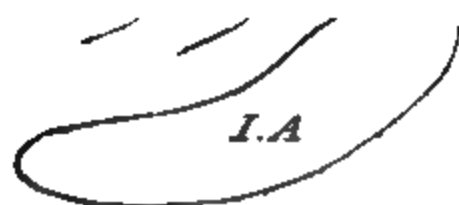
Fig. 51.[1]—Processus vaginalis in transverse section. *T*, testicle; *I.A*, iliac vessel; *P.G.*, plica gubernatrix and gubernaculum; *P.V.*, processus vaginalis; *Int. O* and *T*, internal oblique and transversalis; *E.O*, external oblique.

versalis. The plica gubernatrix also dwindles in its downward course, and ceases to project into the lumen of the canal. From these appearances it may be inferred that at the fifth month the processus vaginalis is a funnel-shaped canal, wide above and

[1] I am indebted to the managers of the *British Medical Journal* for the use of this and other blocks.

pointed below; moreover, they do not favour the supposition that it has been produced by a force acting from within the abdomen, but rather by traction applied to its pointed extremity.

In older fœtuses, such as those of the sixth, seventh, and eighth months of intrauterine life, the gradual progression of the processus vaginalis into the scrotum can be traced by dissection, and the mechanism of the process has been fully described by numerous distinguished observers. It is sufficient for the present to say that it always precedes the testicle towards the scrotum, and it must be admitted that, as it nears its completion, it ceases to possess a pointed extremity, and even becomes more capacious towards its lower part. As we proceed arguments will be advanced to show that, after its muscular structure has become definitely established, the gubernaculum is capable of exerting a certain degree of traction upon the structures to which it is attached. The processus vaginalis is one of these structures, and the weight of evidence seems to favour the theory which attributes its production to the action of the gubernaculum. Perhaps it is unnecessary in the beginning to imagine an active contractive effort, and it may be urged that, at the time the processus vaginalis appears, the gubernaculum is structurally incapable of contraction. It is difficult to say at what moment tissues become capable of contraction. The heart beats before its walls show traces of conversion into muscle, and therefore the above is at least a doubtful argument. But when the phenomena of the infantile hernia and of congenital cæcocele are considered, it will, I think, be evident that the gubernaculum has great capabilities of moving the peritoneum, and can also produce from it hernial sacs—sacs in every way analogous to the processus vaginalis. This question, together with an account of the relations which the processus vaginalis ultimately acquires to the testicle, the vas deferens, the spermatic vessels, and also to the gubernaculum and cremaster, may be conveniently deferred for a while.

The Transition of Sub-peritoneal Fat and Lipoma of the Spermatic Cord.

It is of interest to remark that the processus vaginalis is accompanied towards the scrotum by a quantity of sub-peritoneal

tissue and fat. In two full-grown fœtuses which I have examined, the fatty prolongation was very obvious, and in one caused a slight projection at the external abdominal ring. The sub-peritoneal fat of the fœtus is quite unmistakable, and disposed in small greyish lobules, quite unlike the fine granular fat of other regions. The import of this observation is that there is every reason to believe that the fat which migrates into the scrotum is the source of lipomata of the spermatic cord. Specimens of this rather common affection [1] which I have dissected are in the museum of St Bartholomew's Hospital,[2] and they show that the tumour is in intimate relation with the spermatic vessels, and therefore in the position which sub-peritoneal fat might be expected to occupy. In these cases the lobes of fat were not continuous with that inside the abdomen, but, as Mr Hutchinson shows, this circumstance has been observed in cases of the same description.

The Gubernaculum Testis.

This structure has already been mentioned several times, and the first trace of it was noted in the histological sections of the human embryo of the tenth week of intrauterine life; and at the twelfth week it could easily be seen with the naked eye. Few things have given rise to so much controversy, and those who are interested in the matter will find the views of the various authorities, both ancient and modern, summarized in the memoirs of Cleland,[3] Godard,[4] Bramann,[5] in the joint memoir of Debierre and Pravaz,[6] and elsewhere.[7]

It would not, I think, serve any useful purpose to recapitulate

[1] For cases of the same sort see Curling, *On the Testicle*, p. 556; also *Path. Trans.*, vol. xxxvii., 1886, shown by Mr C. Stonham; also a paper by Mr J. Hutchinson, jun., p. 451 of the same volume, in which the subject is fully discussed.

[2] Sp. 2812a.   [3] *Mechanism of Gubernaculum Testis*, 1856.

[4] M. E. Godard, " Études sur la Menorchidie et la Cryptorchidie chez l'homme," *Comptes Rendus de la Soc. de Biologie*, Paris, 1857, p. 315 *et seq.*

[5] Bramann, *Archiv für Anat. und Phys.*, 1884, p. 310 *et seq.*

[6] Ch. Debierre et J. Pravaz, Contribution a l'étude du Muscle Cremaster, du Gubernaculum Testis et de la Migration Testiculaire, *Lyon Médical*, 1886, p. 101 *et seq.*

[7] Tourneaux et Herrmann, *Dictionnaire Ency. des Sciences Médicales*, 1886, p. 525 *et seq.*; and Weil, quoted before.

the literary researches of these authors, and in what follows it is proposed to lay stress upon points which seem more particularly worthy of notice, and which have not had the attention they may be thought to deserve.

At the third month a distinction can hardly be drawn between the plica gubernatrix and its contents, the gubernaculum. The two together are a delicate band about $\frac{1}{12}$th inch long, continuous below with the abdominal wall, a little external to the hypogastric arteries, and attached above to the genital string (Pl. XVII. fig. 48), right or left, as the case may be. A proper appreciation of the early upper attachment of the gubernaculum is of some importance, because, as Bramann [1] says, authors are not very explicit in their statements concerning it. [2] For instance, if, as some would have us to suppose, it were thought that the gubernaculum was, from the beginning, inserted into the lower end of the Wolffian body or testicle, a difficulty would arise as soon as an attempt was made to trace corresponding parts in the male or female. Every one would admit that the round ligament of the uterus is analogous to the gubernaculum testis, and yet the round ligament does not accord with current descriptions of the gubernaculum, inasmuch as it is attached neither to the parovarium nor to the ovary itself, but to the uterus. The cause of the dilemma and its explanation are alike obvious, if the earliest insertion of the gubernaculum into the genital string be recognised; later, it will be seen that in the male the gubernaculum acquires, during the 3rd, 4th, 5th, and 6th months, attachments to the epididymis, to the testicle, and to the peritoneum of the back of the abdomen. As it acquires these new attachments it comes to lie behind the vas deferens, which, as Bramann points out, crosses over its uppermost part.

A correct appreciation of the way in which the gubernaculum attaches itself first to the vas, then to the vas and epididymis, and afterwards to the testicle as well, explains several anomalies. For instance, it occasionally happens that whilst the testicle and epididymis is retained within the abdomen by adhesions or

[1] Ibid., p. 320.

[2] Quain's Anatomy, 9th ed., vol. ii. p. 898; also fig. 805; also Henle, Handbuch der Eingeweidelhere des Menschen, 1886, p. 340, fig. 255.

other causes, nothing but the vas deferens, together with a processus vaginalis, reach the scrotum.[1] Or, as Cloquet,[2] Curling, Follin, and Godard have shown, the vas and epididymis may proceed towards the scrotum, whilst the body of the testicle remains within the abdomen. A specimen in Guy's Hospital Museum[3] illustrates this fairly well. My note of the specimen says, that on the right side the testicle is within the scrotum, but that the tunica vaginalis is patent, forming the sac of a congenital hernia. On the left side the testicle is undescended, and just within the internal ring. The epididymis is apparently pulled away from the testis, and lies within the neck of a process of peritoneum which occupies the inguinal canal. The peritoneum in the vicinity of the testicle is drawn into folds and pleats as if by dragging. The account which has been given of the superior attachments of the gubernaculum would explain these anomalies if two assumptions be allowed: first, that the upper attachments of the gubernaculum sometimes fail to develop properly; and, secondly, that the gubernaculum is capable of dragging the testicle through the abdominal wall, and finally depositing it in the scrotum, or elsewhere. With regard to the first point, I think it will be allowed that if it can be shown that the upper end of the gubernaculum may have no attachment at all, either to the vas deferens, the epididymis, or to the testicle, it will be admitted that they may be sometimes deficient in a less degree. In a very large and full-term anencephalic monster, the scrotum had exactly the appearance which it presents in cryptorchids, very small and curiously pinched together. When the abdomen was opened there was only a trace of a processus vaginalis on either side, but the gubernaculum was large and well developed. On the left side, however, the gubernaculum, instead of having its ordinary connections, spread out in a thin and wide leash of fibres, contained within a fold of peritoneum (fig. 52). On the right side of the body the attachments of the gubernaculum seemed to be

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[1] There is a specimen which illustrates this in the museum of University College, Sp. 1187.

[2] Cloquet, *Recherches Anatomiques sur les Hernies de l'Abdomen*, Paris, 1817, p. 23 *et seq.*

[3] Sp. 2339[30].

normal.[1] It is also not without interest to note the condition of the scrotum ; it looks as though the testicles had sent word to say they were not coming, and, in consequence, it had not developed. Perhaps I may mention here an embryo between the 3rd and 4th months,[2] in which, had it arrived at maturity,
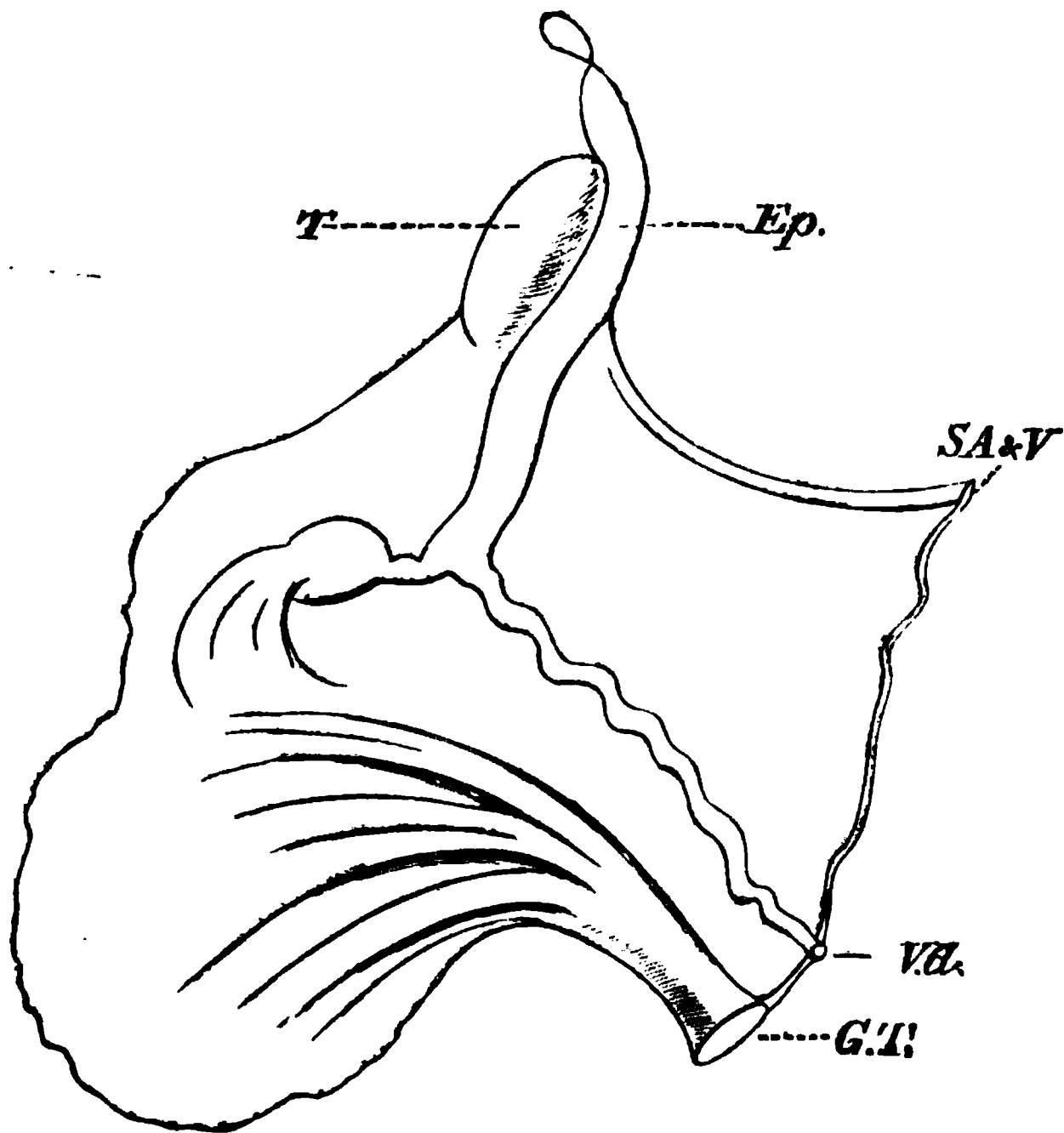

Fig. 52.—*T*, testicle ; *Ep.*, epididymis ; *SA* and *V*, spermatic artery and vein ; *V.d.*, vas deferens ; *G.T.*, gubernaculum testis.

the state of affairs would have been exactly the reverse. In this specimen the testicles and gubernacula seemed as well developed as they usually are at that age, but no trace of a penis or scrotum or anus could be found, although there were one or two indistinct pores in the perinæum. Obviously, in this case, the testicles could never have accomplished their transition.

The second assumption, that the gubernaculum is capable

[1] This specimen is in the museum of St Bartholomew's Hospital, No. 3607a.
[2] Also in the museum of St Bartholomew's Hospital, Sp. 3670b.

of traction, has been maintained by some authors and denied by others. Up to this point the present inquiry has favoured the views of Cleland,[1] Sappey,[2] and Kölliker,[3] who seem to believe that in the transition of the testicle the gubernaculum is passive, but that, whilst the testes themselves do not move, their surroundings grow, and, at the same time, the gubernaculum shortens but does not retract—a process analogous to those which produce the relations of the spine and its contents. However, these hypotheses fail to account for certain interesting phenomena which sometimes attend the transition of the testes. The muscular structure of the gubernaculum is, I think, unquestionable, and it seems irrational to deny its tissues the exercise of their function, namely, that of contraction. Moreover, in a moment we shall see that the lower muscular fibres of the gubernaculum are found to be attached—in addition to the pubes, root of penis, and scrotum—in the perinæum and in Scarpa's triangle. Is it not significant that the testicle sometimes migrates into either of the last-named regions ? Sometimes it lies close to the anus; in case mentioned in the *Lancet*[4] it was two centimetres from that orifice and immovably fixed, and presently other instances will be forthcoming. Now it seems hard to conceive how the testicle could have arrived in this position by any process of growth and development. Moreover, during the last stages of the transition, the pyriform portion of the gubernaculum shortens. In a fœtus, 12 inches long, from crown to sole of foot (the legs outstretched), and which had a mesorchium and gubernaculum the same as that figured in an earlier part of this lecture (fig. 49), the plica gubernatrix and the portion of the gubernaculum between its layers measured $\frac{3}{8}$ inch long; whilst in a fully-developed fœtus, $15\frac{1}{2}$ inches long, and in which the testicle was descended and the processus vaginalis capacious, on looking within that pouch there was no plica gubernatrix or trace of the part of the gubernaculum which lies within that fold of serous membrane. Perhaps these fœtuses place the matter in too favourable a light, and there-

[1] Cleland, *Mechanism of the Gubernaculum Testis*, Edinburgh, 1856.
[2] Sappey, *Traité d'Anatomie Descriptive*, vol. iv. p. 581.
[3] Kölliker, *Entwicklungsgeschichte*, p. 997.
[4] Baudry, *Lancet*, Sept. 1882, p. 454.

fore a few more measurements ought to be tabulated. It seems as though the pyriform portion of the gubernaculum does not bear a very constant proportion to the size of the fœtus. It was always measured from within the peritoneum and as it lay in the plica gubernatrix; the extra-peritoneal portion, that which spreads out to the pubes, scrotum, and perinæum, could not always, for obvious reasons, be measured.

For the present, instead of pursuing this line of argument any further, the lower attachments of the gubernaculum may be mentioned. This branch of the subject has been rendered clear and familiar by the writings of Curling,[1] and therefore a brief description will suffice. Since, however, that author based his observations mainly upon dissected

No.	Size of Fœtus.	Position of Testis.	Length of Gubernaculum.
1	7 in.	Within abdomen.	Pyriform $\frac{1}{16}$ in.; leash $\frac{4}{16}$ in.
2	8¼ in.	Within abdomen.	Pyriform $\frac{3}{16}$ in.
3	8½ in.	Within abdomen.	Pyriform $\frac{1}{16}$ in.; leash. $\frac{4}{16}$ ends on tuber ischii.
4	12 in.	Within abdomen.	Pyriform $\frac{9}{16}$ in.
5	15½ in.	Fully descended.	None.
6	16 in.	On crest of pubes; processus $\frac{4}{16}$ in. further.	Pyriform $\frac{3}{16}$ in.
7	17½ in.	Bottom of scrotum.	Barely $\frac{3}{16}$ in.
8	19 in.	Bottom of scrotum.	$\frac{3}{16}$ in.

specimens, it is proposed, where necessary, to mention the appearances seen in histological sections, prepared as usual by the paraffin method. At the third month of intrauterine life, the lower end of the gubernaculum looks to the naked eye as if it ended at the peritoneum; but, as we have seen, its tissues can be followed in the histological sections into the substance of the abdominal wall. Here they enter the hollow of the descending cremaster and external spermatic fascia, interlacing and interpenetrating the fibres. At this age, moreover, the gubernaculum consists of two sorts of tissues. Its main bulk is made up of round and spindle-shaped cells, each with a deeply-stained, round or oval nucleus. Many of the elongated cells seem to run from the abdominal wall towards

[1] T. B. Curling, *A Practical Treatise on the Diseases of the Testicles*, 4th ed., 1878, p. 17 *et seq.*

the genital string, and they have a decided likeness to unstriped muscular tissue, and, as that substance is afterwards found in abundance in the place they occupy, it is probable that they are of that nature. The other tissue of which the gubernaculum is composed is that which I have previously spoken of as the ascending cremaster. This consists of a few of the innermost muscular fibres of the abdominal wall, which runs a short distance along the gubernaculum, lying immediately beneath its peritoneal investment. At the third month their presence can just be recognised, at the fifth they are no longer doubtful, and at the seventh or eighth are abundant and distinctly striated. These ascending fibres have been recognised from the time of John Hunter, and since then most authors have acknowledged their existence.[1] They are better marked in some animals than in man; for instance, in the hedgehog they are very easily seen, and Hunter seems to have derived his ideas from that animal. Their presence is also clearly shown in various series of histological sections of rabbits' embryos, ranging from the 15th to the 17th day after impregnation.[2]

The gubernaculum grows rapidly after the third month, and the part of it immediately below the testicle assumes a bulbous shape, and, when quite fresh, looks dense and greyish-white. Below this bulbous part its lower end spreads out in a leash of unstriped muscle fibres, which seem both to blend with and pierce the abdominal wall, and which can be seen quite plainly

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[1] *Observations on Certain Parts of the Animal Oeconomy*, by John Hunter, 1786.

[2] Quite recently (Jan. 1888), Dr Klein has kindly sent me a memoir by Professor Weil (" Ueber den Descensus Testiculorum nebst Bemerkungen ueber die Entwickelung der Scheidenheute und des Scrotums," *Zeitschrift für Heilkunde*, Bd. v., 1884, p. 225 *et seq.*). In this memoir a full historical *resumé* is given of the gubernaculum and processus vaginalis. Moreover, the subject is studied by means of histological sections, and it is not without interest to compare the results with those which I have from an independent standpoint given. This author (p. 248) describes and depicts the gubernaculum and processus as being clearly established at the end of the second month. As regards the processus this seems too early, and, judging from his sketch, the embryo in which the appearances were seen was as old, or even older than, those which I have considered to have been of the third month. However, the determination of the age of embryos is always a doubtful point. Weil recognises in the gubernaculum both spindle-shaped cells and striped fibres, together with some blood-vessels, which arise from the spermatic and epigastric arteries (p. 254).

by dissection. At about the fifth month these fibres spread out fan-like in their main directions, namely, into Scarpa's triangle, upon the pubes and root of penis, and towards the scrotum (Pl. XVII. fig. 53). By the sixth month, in a foetus which measured 8½ inches long with its legs extended, a thick fasciculus passed onwards into the perinæum, where it ended in the tissues about the anus and over the tuber ischii. In larger foetuses the perinæal band of the gubernaculum is oftentimes better developed. In speaking of either the perinæal prolongation of the gubernaculum or that into Scarpa's triangle, which from its position and direction may be called its saphenous prolongation, it is necessary to use guarded language, for although they are both met with very frequently, yet their presence cannot always be affirmed. However, it is difficult to trace fibres of this description amongst foetal tissues, and at some period before the end of foetal life the perinæal band would probably exist. It is otherwise with the saphenous band, for although I have found it in most foetuses which had reached the fifth or sixth month, yet in those which were older it was unrecognisable, and therefore it may be concluded that it is transitory. The fact that it does exist helps to explain that variety of malposition of the testicle which is called crural inclusion. Medical literature contains the records of a great many cases of this, and I have to thank Mr Page of Newcastle for having sent me a portrait of a typical example.[1]

In a series of sections of the scrotum and perinæum of a mature foetus, and in which the testes were fully descended (Pl. XVII. fig. 54), these perinæal fibres were present, and also others, which united the processus vaginalis to the bottom of the scrotum. There are other circumstances which would render the existence of these perinæal fibres highly probable, even if the foregoing evidence was wanting. A little while ago it was remarked that the testicle occasionally lay in the perinæum, and I have before me a sketch, which Mr J. H. Morgan kindly sent me, of a case of a child in which the right half of the scrotum was smaller than the other, and the corresponding testis in the perinæum. But the most significant point in the

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[1] Kocher, *Die Krankheiten der Männlichen Geschlechtsorgane*, 1887, p. 570 *et seq.*, collates a number of cases of malposition.

case was the presence of a band of fibres which held the right testis in the perinæum near the anus. This band, as Mr Morgan's note says, was attached near the anus, and caused the skin to pucker when the testicle was pushed forwards. It seems as though it were a common thing in these cases for the testicle to be held in the perinæum by some sort of a band. Mr Treves has also informed me of a similar case, and in which, when the band had been divided with a tenotomy knife, the testicle was replaced in the scrotum. Mr M'Carthy[1] mentions a case, and Cloquet, in another, actually had an opportunity of dissecting out the band.[2] The perinæal attachments of this band may be either the tuberosity of the ischium, the external sphincter, or the skin. In Cloquet's case it was attached to the tuber ischii. Perhaps it may not be out of place to mention that great caution is requisite in dealing with these cases. There is reason to think that the processus vaginalis may accompany the testicle in its abnormal excursion, and remain in communication with the general peritoneal sac. The consequences which may ensue, if, in the course of operations for the replacement of the testicle, the processus vaginalis was opened without special precautions, are familiar to every surgeon. Mr M'Carthy in his article mentions two deaths from peritonitis after operations upon cases of this kind.

A last reference to the scrotal fibres of the gubernaculum may be permitted, more especially as doubt has been cast upon their existence.[3] Their presence is usually affirmed, because an attempt to draw the newly-descended testis upwards out of the scrotum causes the end of that sac to invert, and, moreover, because they can be seen by dissection.[4] Both of these statements are, I think, correct; and, in addition, the presence of scrotal fibres is shown in the series of sections of a fully developed scrotum (Pl. XVII. fig. 54). Nevertheless, those who have attempted to trace smooth muscle fibres with the scalpel will readily understand why opinions vary.

It may be advantageous to enumerate the attachments of the

[1] Quain's *Dic. of Medicine*, 1882, p. 1606.

[2] *Recherches sur les Causes et l'Anatomie des Hernies Abdominales*, Paris, 1819, pp. 24, 25.

[3] Bramann, *ibid.*, p. 334.

[4] Curling, *Diseases of the Testis*, 4th ed., 1878, p. 17 *et seq.*

gubernaculum in the order in which they seem to develop, viz., (1) abdominal; (2) pubic and saphenous; (3) perinæal and scrotal. Placing the saphenous upon one side as being, perhaps, inconstant, the functions attributed to the abdominal, pubic, and scrotal are as follows:—The testicle is brought by the abdominal into the ostium of the processus vaginalis, through the canal by pubic, and deposited in its resting place by the scrotal. With regard to the first of these actions, it may be said that the process is not quite so simple as at first glance it seems to be. If we compare the position of the testicle of a five months' fœtus (figs. 51 and 57) with its position in one of the seventh month (fig. 49), it is evident that in the younger embryo the gland lies close to the ostium of the processus vaginalis, whilst in the older embryo it seems to have re-ascended a little way into the abdomen.[1] This re-ascent, which seems a constant occurrence, has been permitted by a luxuriant growth of the mesorchium and by an elongation of the intra-abdominal portion of the gubernaculum. The occurrence is unexpected, and seems to indicate a peculiarity in the action of the gubernaculum, and, in a sense, to detract from the importance given to its abdominal attachment. By its abdominal attachment the gubernaculum can only for a time hold the vas deferens, and afterwards the epididymis and testicle near ostium of the processus vaginalis. The actual passage of the testicle through the inguinal canal begins during the seventh month, and by that time the vaginalis is ready for its reception, and the gubernaculum has acquired other attachments to the pubes, which may be supposed to afford it a fixed point from which to act and draw the gland, first into the ostium, and afterwards into the canal. The scrotal band, however, seems deficient in firm attachments and unfitted for the duty it is supposed to perform. Various circumstances indicate that, in bringing the testicle through the abdominal wall, the gubernaculum must exert a certain amount of force. For instance, if a fœtus be chosen in which the testicle is about to pass through the abdominal wall, and traction be made upon the gubernaculum, it is clear that as the testicle travels towards the scrotum, not only the mesorchium and its contents and the processus vaginalis, but also the

[1] Bramann, p. 620.

peritonæum of the back of the abdomen, moves with it. In consequence of this locomotion of the serous membrane, the cæcum and ilium on the right side, and the sigmoid flexure upon the left, become lower in the abdomen, a circumstance upon which both Scarpa and Wrisberg have commented,[1] and as I proceed other reasons for this belief will be forthcoming. Now, it is obvious that the scrotal attachments of the gubernaculum are ill fitted to afford resistance to the action of the muscle, and I conceive that it is by means of its well-attached perinæal fibres that the gubernaculum is enabled to effect its purpose, the scrotal band merely influencing the final position of the gland.

In attributing the final passage of the testicle through the abdominal wall into the scrotum to the traction of the gubernaculum, I have not thought it necessary to parade the various theories which have been offered as an explanation of the phenomenon. The weight of the organ has been invoked, also certain suppositious respiratory efforts, and, finally, a sort of hernial protrusion.[2] The first of these theories has been demolished by Sappey, who remarks that during the period of transition the fœtus usually lies in the uterus with its head downwards. The second theory calls for no comment, for there is nothing to show that the fœtus breathes before birth; rather the contrary. The last theory is more plausible, and has recently been revived,[3] but seems to rest upon an obvious ambiguity. The term hernia is used in two different senses. Sometimes it implies merely an anatomical condition, namely, the escape of organs from their containing cavities; at other times the word hernia is used to connote a pathological change; but, used in its pathological and not in its anatomical sense, it is clear that the word hernia ought not to be used in explaining the transition of the testicle, for the simple reason that the pathology of hernia is quite undecided. The question still remains to be settled whether inguinal hernia is due to (a) a defect in the abdominal walls; (b) an elongation of the mesentery; or (c) a general defect of the peritoneum. However this may be, I hope presently to adduce evidence to show that

[1] See paper by author, Roy. Med. Chir. Trans., vol. lxix. p. 505.
[2] Sappey, Traité d'Anatomie Descriptive, vol. iv. p. 606.
[3] J. Bland Sutton, An Introduction to General Pathology, 1886.

the gubernaculum testis may have something to do with the pathology of congenital cæcocele and of infantile hernia.

The Cremaster.

The anatomy of the cremaster is well known, and does not call for lengthy notice. Where its fibres are attached to Poupart's ligament, they are also continuous with the internal oblique muscle. Its inner tendinous attachment is into the pubes, close to the insertion of the internal oblique muscle.[1] Its loops descend in front of the spermatic cord, and become larger and longer as they descend, and some of them may invest the testicle. Upon these points there is perhaps no dispute, but a variety of opinions prevail as to the parentage of the muscle. It would not be inaccurate to say that there are two main views upon this question. Some think that the cremaster is created out of those striped muscular fibres which ascend the gubernaculum from the abdominal wall, and which I have called the ascending cremaster. Others believe that it is derived from the lower fibres of the internal oblique, and which have accompanied the testis in its transition.[2] The first of these opinions originated with Hunter, who saw that the fibres of the ascending cremaster of the ram became inverted when the gubernaculum was pulled downwards beyond the abdominal wall.[3] Judging from its characters in the human embryos which have been described above, it is probable that this same thing would happen to them. I have assumed in the foregoing that the chief labour of transition falls upon the smooth muscular elements of the cremaster. It cannot be denied, however, that the striped fibres may also assist and help to draw the testicle as far as their own lower attachments, but obviously not beyond, as some have supposed. The ascending cremaster of the human embryo is so trivial, that perhaps it ought to be looked upon as a mere survival of a muscle which, in some of the lower animals, is more active and better developed.

[1] Quain, 9th ed., 1882, vol. i. p. 32.

[2] *Ibid.*, pp. 7, 8.

[3] A very clear and correct account of the cremaster is given by Debierre and Pravaz (*Lyon Médicale*, 1886), so far as the muscle can be studied by dissection. They also give an excellent epitome of the views of the various authors.

We now come to the second theory, that the cremaster is an appendage of the internal oblique muscle, displaced towards the scrotum by the testicle in its transition. From what has gone before it will be seen that this proposition is only true in a very limited sense, namely, so far as it may be taken to imply that the *descending* cremaster is developed in connection with the oblique muscle. The histological specimens which have been described in the earlier part of this lecture seemed to show that the muscular fibres, which were called the *ascending* cremaster, developed in close connection with the internal oblique; perhaps it would not be incorrect to say that they developed as an outgrowth of that muscle. But it must not be ignored that, at first, no distinction can be drawn between the internal oblique and transversalis muscles, so that the latter might claim a share in the process. However, the part of the proposition which attributes the origin of the cremaster to the transition of the testicle is not borne out by the specimens. They show that the external cremaster develops long before that event, and indeed before the processus vaginalis has appeared. Towards the end of the seventh month of intrauterine life the processus vaginalis is so far ahead of the testicle that it must have anticipated the testicle in any action that organ might have had in carrying down the cremaster. It would be more rational to attribute the formation of the muscle to the gradual advance of the peritoneal pouch, rather than to that of the sexual gland. In the later stages, towards the eighth month of intrauterine life, the processus vaginalis is so voluminous that it would be rash to deny it a part in at least modifying the cremaster; but it is so difficult, perhaps impossible, to dissect the muscle in the fœtus, that I have been unable to obtain definite information upon this point.

The Superior Attachments of the Gubernaculum, the Mesorchium, and Plica Vascularis.

The superior attachments of the gubernaculum have already been described, with the exception of the peritoneal prolongation. It may be remembered that they varied according to the stage of development, the gubernaculum being attached first to

the genital cord, then to the cord and epididymis, and finally
to both of those structures, and also to the body of the testicle.
The prolongation which the gubernaculum sends upwards be-
hind the testicle to the peritoneum is chiefly confined to the
plica vascularis, but it has sometimes a wider distribution. It
was well marked in a fœtus 8½ inches long (legs extended), and
presumably of about the sixth month; and in others, 12 inches
long, and presumably towards the end of the seventh month,
the plica vascularis contained its fibres in great abundance, and
they probably reached the organs with which the fold is at
various times connected, namely, on the right side with the
cæcum, vermiform appendix, or the ilium and mesentery, and
on the left side with the sigmoid flexure. Without doubt, the
main portion passes to the mesentery, which, at the eighth
month, is common to the cæcum and ilium, or to the mesentery
of the sigmoid flexure. Both the plica vascularis and its con-
tents, especially the muscular fibres, are of physiological and
pathological importance. When the lower end of the right
gubernaculum of the fœtus of the seventh or eighth month,
whose mesorchium has been figured in an earlier part of this
lecture (fig. 49), was pulled downwards, the processus vaginalis,
vas deferens, epididymis, testicle, mesorchium, with its plica
gubernatrix and plica vascularis, the cæcum and vermiform
appendix, the ilium and mesentery, and peritoneum of the back
of the abdomen, all glided downwards towards the inguinal
canal and scrotum, and traction on the left gubernaculum had
the same effect upon the sigmoid flexure. The attachment of
the gubernaculum to the various parts of the sexual apparatus
is sufficient to account for their displacement, and the other
viscera follow, because they are connected with the epididymis
by the plica vascularis. Doubtless, the serous membrane of
that fold may be sufficiently inelastic to bear whatever strain
there may be, but presently it will be seen that due regard
must be paid to the upward prolongation of the gubernaculum.
These muscular fibres have an extensive connection with the
peritoneum, which lines the back of the abdomen, and doubt-
less bring about the locomotion of that membrane, which is
seen in the transition of the testicle, and in many cases of
hernia. That the serous membrane of the back wall of the

abdomen is much looser than the rest has been repeatedly pointed out in the earlier part of this lecture; it is underlaid by abundant loose areolar tissue and fat, and is easily displaced and thrown in folds. The peritoneum, which lines the front wall of the abdomen, is, except near the epigastric and hypogastric arteries, intimately bound to the abdominal wall. In adult subjects the union of transversalis muscle, transversalis fascia, and peritoneum is so close, that sometimes it would hardly be incorrect to say that the muscular fibres of the transversalis were inserted into the peritoneum. For these reasons the peritoneum of the front wall of the abdomen is incapable of much displacement, and probably takes but a small share in the formation of large hernial sacs.

Before discussing the other attributes of the muscular fibres, the history of the plica vascularis, considered as a serous fold, may be mentioned. When the testicle glides down the processus vaginalis—which has preceded it—into the scrotum, it retains in a greater or less degree its peritoneal folds. For instance, at its lower end may still be seen in most fœtuses the plica gubernatrix, and from the head of the epididymis another fold, the plica vascularis, runs upwards upon the back of the processus vaginalis towards the abdomen. Owing to its connection with the globus major the plica vascularis is easy to recognise, and it not uncommonly persists throughout life. For instance, Camper,[1] in his *Icones Herniarum*, gives excellent representations of it; Sir Astley Cooper also depicts it;[2] and Sappey[3] says that the visceral layer of the tunica vaginalis forms a sort of small mesentery, which contains the testicular vessels; but none of these authors seem to have recognised the developmental significance of this fold. The plica vascularis is usually distinct in a fœtus in which the testicles have just reached the scrotum, and it extends upwards along the back of the processus vaginalis into the abdomen (fig. 45); or, if that passage has been obliterated, a fold, which occupies its position, extends from the internal abdominal ring towards the mesentery

[1] Camper, *Icones Herniarum*, ed. by S. J. Sœmmerring, 1801, Tab. III. figs. 3 and 4.

[2] Cooper, *Anatomy and Surgical Treatment of Abdominal Hernia*, pl. v. fig. 6, and elsewhere.

[3] *Traité d'Anatomie Descriptive*, vol. iv. p. 602.

either of the cæcum and ilium, or of the sigmoid flexure. The main interest of the plica vascularis depends upon its relation to undescended testis and various forms of congenital hernia.

That the transition of the testis may have an influence upon the last stages of the migration of the cæcum I have elsewhere endeavoured to show,[1] and have published cases in which, when the testicle was undescended and lay within the abdomen, the cæcum remained at or near the liver. On the other hand, I have met with a case in which the right testicle was fully descended, although the cæcum was firmly adherent to the liver.[2] This abnormality occurred in an anencephalic monster, and I am accustomed always to examine these creatures with care, because they seem particularly liable to intrauterine peritonitis and other complaints, and therefore afford most interesting material. The foregoing case has been mentioned, because it tends to place the matter in a light not very favourable to my hypothesis, but not, however, in an absolutely unfavourable light. In the first place, it has merely been claimed that the testicle in its transition *influenced* the *last* stages of the migration of the cæcum, and in the case which has been mentioned the cæcum must have become adherent to the liver at such an early age, that it could neither have been influenced by the movements of the testicle, nor by its own adherence have impeded that organ. Continuing the pathological bearings of the plica vascularis, there is reason to believe that that fold may in another way be a factor in the pathology of undescended testicle. In reading of cases of abdominal inclusion of the testicle, it is impossible not to be struck by the repeated references to the presence of adhesions. Without doubt some of these are simply inflammatory,[3] due to intrauterine peritonitis;[4] but in others it seems safe to infer that the so-called

[1] "Abnormalities of the Cæcum and Colon, with Reference to Development," *British Medical Journal*, September 1882, p. 575.

[2] The specimen is described in *Path. Soc. Trans.*, vol. xxxvii. p. 250, and is in the museum of St Bartholomew's Hospital.

[3] Testicle retained in the abdomen by adhesion to the sigmoid flexure of the colon. John Wood, "Adhesions due to Inflammation from Mesenteric Disease in Fœtal Life," *Path. Trans.*, vol. viii., 1856, p. 265.

[4] Simpson, *Ed. Med. Journ.*, vol. lii. p. 17 *et seq.* We have also to note the possibility that the retained testicle may in some rare cases set up inflammation in its vicinity.

adhesion was in reality the plica vascularis which had persisted in an unusual degree. Such a case as the following is not without significance:—Cloquet found in an aged man the left testicle an inch inside the ring, and fastened to the sigmoid flexure by a band—fibrous, white, round, and very strong.[1] Curling mentions another case of imperfect transition, in which the testicle was adherent to the gut, but his observation is based upon clinical evidence,[2] and I am unable to ascertain that he clearly appreciated that the so-called adhesion was of the nature of the plica vascularis. However, he agrees with Cloquet in believing that congenital bands, which seem to possess the characters of the plica vascularis, may impede the transition of the testicle.

The plica vascularis seems at times to play a different part. It occasionally happens that the cæcum, vermiform appendix, ilium, or sigmoid flexure may accompany the testicle into the scrotum, and give rise to various forms of congenital hernia. In cases of this sort a peritoneal band is very often found passing upward from the head of the epididymis to the herniated gut. The spermatic vessels usually lie in this fold, and it has the characters of the plica vascularis. Wrisberg,[3] Lobstein,[4] Sandifort,[5] and others [6] have mentioned this circumstance, and the first and last named authors seemed to appreciate clearly the meaning of the connection between the gut and the testicle. They assumed that, owing to persistence of the plica, the gut had been dragged down by the testicle in its transition. However, although there is an element of truth in this assumption, there is reason to doubt whether it is the whole truth. I have mentioned elsewhere [7] a congenital cæcocele, which I was so fortunate as to find in an infant, and in which there was no fold

[1] *Recherches sur les Causes et l'Anatomie des Hernies Abdominales*, Paris, 1819, p. 23.

[2] *Ibid.*, p. 24.

[3] Wrisberg, "Observationes Anatomicæ de Testiculorum ex Abdomine in Scrotum descensu," &c., *Comment. Soc. Reg. Scient.*, Gotting., 1800, p. 173 et seq.

[4] Quoted by Wrisberg.

[5] Sandifort, *Icones Herniæ Inguinales Congenitæ*, 1781, p. 12 et seq.

[6] Scarpa, *On Hernia*, Wishart, Edinburgh, 1814, p. 194, art. on the "Natural Fleshy Adhesion"; also F. Treves, "Hernia of the Cæcum," *Brit. Med. Jour.*, Feb. 19, 1887, p. 385.

[7] *Med. Chir. Trans.*, vol. lxix. p. 505.

extending from the testicle to the gut, but in its place a quantity of unstriped muscular fibres, which turned upwards from the perinæum and back of the testicle towards the cæcum and peritoneum of the back of the abdomen. These muscular fibres are clearly the upward prolongation of the gubernaculum, which has already been mentioned, and which has been claimed to aid in the locomotion of the peritoneum of the back of the abdomen which accompanies the transition of the testicle. In this respect they seem to have had a share in causing the cæcocele. In another cæcocele sent to me by my friend, Mr Maud, the muscular band was also present; and Professor Cunningham has very kindly written to inform me of a case in which there was a band of fibres so strong "that it does not fall far short of the platysma," and which he considers "as having been the active agent in producing the hernia (of the cæcum), and as having become hypertrophied in the process." In this case there was also a second isolated peritoneal pouch, which I will mention again in speaking of infantile hernia.

The upward prolongation of the gubernaculum is also met with under other circumstances. Normally it persists as the muscular fibres which Henle and Cruveilhier call the internal cremaster;[1] and presently it will be seen to have an important bearing upon the pathology of infantile hernia. But before mentioning this, perhaps I may point out that the plica vascularis is found very commonly in congenital and funicular herniæ, and is an important guide to the position of the spermatic vessels. It is unnecessary to point out what serious results ensue when these vessels are injured in the performance of operations.

The peritoneal prolongation of the gubernaculum is, I think, an important factor in producing certain sorts of hernial sacs, especially the sacs of infantile hernia. This opinion is based upon evidence derived from such specimens as the following :—
There is a specimen in the museum of St Bartholomew's Hospital,[2] which I have had the opportunity of dissecting, in which the processus vaginalis is represented by a long tube,

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[1] Since my paper upon Encysted and Infantile Hernia, and in which this view was put forth, a similar observation has been made quite independently by Debierre and Pravaz (ibid., p. 143), but without reference to hernia.

[2] Sp. 2140B.

which extends from the internal abdominal ring to just above the epididymis. This tube communicates with the general cavity of the peritoneum by a small aperture, a quarter of an inch in diameter, which occupies the usual position of the internal abdominal ring external to the epigastric artery. A probe introduced into this opening showed that the processus vaginalis was occluded an inch from the upper end, but in the remainder of its extent its cavity was almost half an inch in diameter above and one and a half below. Behind the superior part of this serous tube a hernial sac protruded from the peritoneum in such a way that the anterior wall bulged slightly into the cavity of the processus vaginalis. Attached to the lower extremity of this protrusion and to its posterior wall were strong bands of unstriped muscle fibre intimately related to the spermatic vessels. The end of the sac to which these were attached was conical and sharply-pointed. This specimen I have described elsewhere, and considered it to have been a variety of infantile hernia.[1] It is perhaps unnecessary to argue that the origin of the pointed hernial sac was due to the action of the muscular fibres, and, further, that these fibres were a part of the peritoneal prolongation of the gubernaculum. The isolated peritoneal pouch seen in Professor Cunningham's specimen lay towards the outer side of the true sac of the congenital cæcocele; and although it had no connection with the abdominal peritoneum, " was drawn out above into a fine point . . . . . and has doubtless been dragged down by some stray fibres " (of the gubernaculum). In other cases of infantile hernia the band is also clearly marked, and it may perhaps suffice to mention a single well-marked instance. By an infantile hernia is meant a variety of congenital hernia, in which the processus vaginalis is not obliterated, but remains in the condition in which it is found in congenital hernia, except that it may be occluded to a greater or less degree near the internal abdominal ring. However, occlusion is probably the exception, and when it does take place the manner of its occurrence can be traced. In addition to this non-obliteration of the processus vaginalis there is, in infantile hernia, a second pouch of peritoneum, which descends behind the other and bulges into it.

[1] *Med. Chir. Trans.*, vol. lxix. p. 513.

Sometimes the projection is slight, but at others is so great that the true hernial sac—*i.e.*, that which contains the herniated viscus—almost seems to hang from near the ostium of the processus vaginalis, like a sac pendent from the ring. It may render this brief description clearer if I add that, to gain an entrance into the true hernial sac from in front, it would be necessary, first of all, to cut the front and back walls of the non-
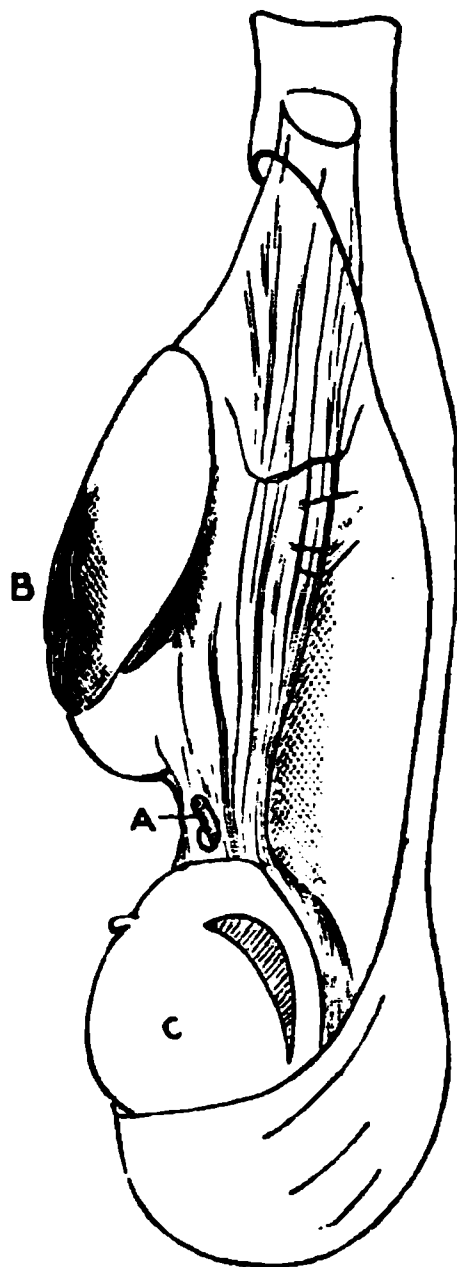

Fig. 55.—Infantile Hernia. A, upward prolongation of gubernaculum with spermatic artery in its midst ; B, true spinal sac with double walls ; C, body of testicle.

obliterated processus vaginalis, and then the wall of the true hernial sac, as Hey[1] calls it. There is reason, however, to believe that the pathology of infantile hernia is in some way connected with the plica vascularis, because in some specimens the remains of that fold can be seen extending from the epididymis to the lower end of the true hernial sac.[2] In other

[1] It is interesting to note that in Hey's case of infantile hernia the sac contained the cæcum.

[2] *E.g.*, Sp. R. 24, St Thomas's Hist. Museum, *Med. Chir. Trans.*, fig. 4, p. 493.

cases, in which the serous membrane has probably been dissected away, instead of the plica a strong band of smooth muscle fibres unites the back of the epididymis to the extremity of the true hernial sac (see fig. 55). This band represents the peritoneal prolongation of the gubernaculum, and, besides being intimately related to the spermatic vessels, runs upwards along the back of the true hernial sac towards the abdomen. When we recall the influence which the gubernaculum has in forming the processus vaginalis itself, or, as Cloquet has maintained, hernial sacs of various sorts, it seems reasonable to argue that it is an important factor in the pathology of infantile hernia.

Relation of the Vas Deferens and Spermatic Vessels to Processus Vaginalis. The Recurrent Branches of the Spermatic Artery.

It is unnecessary to premise, that as the testicles migrate down the processus vaginalis, the spermatic vessels and vas deferens accompany them, and acquire certain definite relations which it is important to recognise. If a fœtus be chosen in which the testicles have completed their migration, but in which the processus vaginalis is capacious and still in communication with the peritoneum, the relations of the vas deferens and spermatic vessels are usually as follows:—The artery and vein run from the upper part of the abdomen to the outer side of the ostium of the processus vaginalis, and then along the back of that sac, lying in the plica vascularis, as far as the epididymis, where they divide into their two main divisions, one going to the body of the testicle and the other to epididymis; the vein usually lies to the inner side of the artery. The vas deferens, on the other hand, runs upwards from the neck of the bladder round the hypogastric arteries towards the inner and lower part of the ostium of the processus vaginalis, and thence along the posterior wall of that sac, to reach the globus minor. In the last part of its course the vas deferens lies internal to the vessels, and sometimes quite apart from them (fig. 55). These relations are interesting, because they help to explain the separation of the vas deferens from spermatic vessels seen in many cases of hernia. The London museums contain so

many examples of this condition, and it seems such a common and well-known occurrence, that it is perhaps unnecessary to adduce instances; but in nearly all of them the vas deferens lies well to the inner side of the vein and artery. Lawrence [1] mentions numerous instances of this occurrence, and attributes the separation to the distensile force of the hernia. Later, he says the same condition may be found in a small hernial tumour,[2] and the specimens in museums fully bear out this statement; and they further suggest that mere distension could not have been the sole cause of the separation of the vas from the vessels, but that the predisposing developmental factor which has just been mentioned must also be taken into consideration; indeed, in some instances of congenital hernia, it seems as if the structures in question can never have been together. I hope to deal with this question more fully at another time, and will therefore not endeavour at present to discuss other varieties of the condition.

In endeavouring to ascertain whether the spermatic artery accompanies the transition of the testicle *pari passu* with the peritoneum and processus vaginalis, or whether it was drawn in a greater degree towards the scrotum, several interesting circumstances came to light. Text-books on anatomy usually state that the spermatic artery gives branches to the peritoneum, and on the left side others are frequently supplied to the sigmoid flexure.[3] It suggests itself that these branches may afford information bearing upon the question of the relative movements of the artery and of the peritoneum; and in numerous dissections I have found the spermatic arteries give off recurrent branches to the peritoneum. The largest of these begin near the internal abdominal ring, and run 4 or 5 inches upwards, giving off branches and gradually dwindling (Pl. XVII. fig. 56). The inference to be drawn from their presence seems obvious, namely, that the spermatic artery is displaced more than the peritoneum. But, in addition, the recurrent branches of the spermatic artery seem to have a pathological

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[1] Lawrence, *On Hernia*, p. 212.

[2] *Ibid.*, p. 213.

[3] See more particularly Turner on the existence of an anastomosing system of arteries between the visceral and parietal branches of the abdominal aorta, *Brit. and For. Med. Chir. Review*, July 1863.

bearing, and it is not improbable that they have something to do with the formation of these secondary pouches, which are found upon the hinder wall of the sacs of some congenital hernia. That these recurrent branches may be also found at the back of the processus vaginalis is shown by various specimens. For instance, there is a dried hydrocele in St Bartholomew's Hospital Museum whose vessels have been injected, and in which the recurrent branches are quite clear;[1] also, there is in the Dupuytren Museum a hernial sac, which has been treated in the same way, and which has the same recurrent arteries upon its hinder wall.[2] Now, the principle seems established that vessels which are related as these recurrent branches are to the peritoneum may throw that membrane into folds,[3] and it is not without significance to note that I have found a large obliterated vessel running in the fold of serous membrane, which formed a supplementary sac upon the back wall of a funicular hernia.[4]

The Closure of the Processus Vaginalis.

A number of fœtuses have been examined to see how the processus vaginalis becomes occluded after it has transmitted the testicle. There seems to be, as others have remarked, a strong tendency for it to close in two places, which are some distance apart, namely, just above the testicle and near the internal abdominal ring. This statement is founded upon ordinary anatomical evidence, the processus having been merely slit open with scissors. In some fœtuses the serous canal was so attenuated that it was hard to discern, and it would have been rash to make any positive statement as to its patency or occlusion. But there was no evidence in any case to show that the processus vaginalis closed by adhesion. Its interior was always smooth and shining, like the rest of the peritoneum. Importance attaches to this point, because it has been thought that the processus vaginalis sometimes became closed by adhesions which afterwards became

[1] 2753. [2] Sp. 295.

[3] Treves, *The Anatomy of the Intestinal Canal and Peritoneum in Man*, London, 1885.

[4] This specimen, and another which is of exactly the same nature, are in the museum of St Bartholomew's Hospital, Nos. 2090 and 2140c.

stretched into the sac of an encysted hernia. I have elsewhere endeavoured to combat this view upon various grounds, amongst which, perhaps, the most cogent are, first, that such adhesions have never been seen; and second, that the specimens which have been called encysted herniæ belong to the infantile variety.

In bringing these lectures to a close, I wish to thank Mr D'Arcy Power and numerous other friends for the valuable material they have placed at my disposal. And I am especially indebted to Dr Vincent D. Harris for many acts of kindness, and for his assistance and advice.

ERRATA.

Page 53, line 28, *for* fourteenth *read* fourth.
„ 57, „ 23, *for* 32 *read* 31.
„ 74, „ 10, *for* 23 *read* 33.
„ 74, „ 15, *for* 23 *read* 33.

ON THE NATURE OF LIGAMENTS. PART V. By J. BLAND SUTTON, F.R.C.S., *Hunterian Professor, Royal College of Surgeons.*

Some Vestigial Muscles.

THE posterior interosseous nerve of man's forearm exhibits a peculiarity which, as far as I can judge, belongs to it alone among nerves its equal in point of size. After supplying twigs to the deep layer of muscle on the extensor aspect of the forearm, this nerve ends in a collection of fibrous tissue on the dorsum of the carpus. An inquiry into this singular mode of termination has had the effect of throwing some light on the nature of the tissue in which the nerve terminates.

When the extensor muscles of man's forearm are compared with those of the majority of Quadrumana, we at once observe that man is distinguished from them in the absence of a second extensor for the medius and annularis, whereas most monkeys possess a double set of long extensors. We may distinguish the muscles in question by the name of the finger to which each belongs, thus—

MAN.	MONKEYS.
Ex. secundus.	Ex. secundus.
„ indicis.	„ indicis.
	„ medius.
	„ annularis.
„ minimus.	„ minimus.

A consideration of these facts induced me to believe that the solution of the problem I had set myself would be found if the fate of the medius and annularis muscles could be determined satisfactorily.

The inquiry has been full of interest, inasmuch as it has brought to light one of the most striking examples of muscular migration known to me, and the conclusion to which I have arrived may be expressed as follows:—

The second set of short extensors originally arose as a common muscle from the external humeral condyle and adjacent parts of

the olecranon, discrete tendons passing to join the tendons of the common extensor; each part of this second extensor muscle had a small belly but a long tendon, and received the nerve supply near its origin, the posterior surface of the ulna being practically unoccupied. This primitive condition, which may be studied in kangaroos and phalangers, became disturbed by the migration of the *ext. sec. internod. pollicis* lower down the ulnar shaft; gradually the *indicis* followed, and acquired a new attachment to the ulna below the secundus; in the same way the *medius* migrated from the external condyle to the ulna below the indicis; whilst in a few rare instances the *annularis* muscle may acquire a new origin from the ulna below the medius. As far as I can ascertain, the *minimus* never leaves its old attachment to the humeral condyle.

In man the *medius* and *annularis* are not normally represented, but when they reappear as anomalous muscles they are in most cases attached to the lower end of the ulna. When these two muscles are not functional a band of fibrous tissue may be often detected containing numerous strands of tendon, arising from the lower third of the dorsal surface of the ulna below the indicis, and becoming lost on the carpus. In one case I could trace the tendon in the fascia until it was lost in the belly of the extensor minimus. This fibrous tissue is probably the degraded representative of the medius and indicis muscles; and what is equally significant, the posterior interosseous nerve ends in this tissue.

If man is descended from ancestors normally supplied with an extensor medius and ex. annularis, we ought to find these muscles very frequently in a functional condition, and the more so, as these two muscles are so constantly represented in the group of mammals zoologically so closely allied to man as the anthropomorpha. This is actually the case. Indeed, a medius or annularis muscle, or both muscles concurrently, are recognised as common muscular anomalies in anatomical text-books. So frequently are these muscles present in a functional condition that a session rarely passes without their presence being detected.

In some cases these muscles are only represented in part, usually the distal portion. In cases it is not unusual to find the anomalous muscle designated extensor brevis digitorum manus.

More briefly summarised, the matter stands thus:—

1. The *extensores secundus, indices*, and *minimus* are the remnants of a second long extensor, which originally arose from the external condyle of the humerus and corresponding surface of the olecranon.

2. The *ext. minimus* maintains its old attachments, the remaining slips having migrated down the ulna.

3. The *ext. medius* and *annularis* slips have regressed into fibrous tissue, but not infrequently they reappear as functional muscles.

4. As these muscles *migrated* from the neighbourhood of the elbow, they carried with them the branch of the musculo-spiral nerve which supplied them; this subsequently became the posterior interosseous nerve. Its apparently meaningless termination on the back of the carpus is probably due to its being involved in the regression of the *medius* and *annularis* muscles.

5. The *ext. primi internodii pollicis* must be regarded as a segment of the long extensor, which has been *supplanted* by the *ext. secundus.*

The translocation of nerves in consequence of the migration of a muscle, or part of a muscle, is a fact of considerable interest, and one concerning which we know very little. Indeed, the only case known to me, beside that of the posterior interosseous nerve, is the instance described by Dr St John Brooks,[1] in which he seeks to explain in a measure those not infrequent cases in which the ulnar nerve supplies the radial head of the flexor brevis pollicis muscle.

In this case the ulnar branch may possibly be carried over the long flexor tendon by an aberrant slip of the flexor brevis pollicis which, arising on the ulnar side of the pollex, wanders across the thenar eminence to be inserted into the radial sesamoid. The subject is one of importance and great interest, requiring patient inquiry for its satisfactory elucidation, but it will well repay investigation.

As an appendix the various dissections have been arranged in a tabular form for the convenience of those likely to look into the question. All the mammals mentioned have been specially dissected by me for the elucidation of the question.

[1] *Jour. of Anat. and Phys.*, vol. xx. p. 641.

In the first group the second set of long extensors arise from the ex. condyle and adjacent portions of the olecranon :—

Belideus breviceps. | *Macropus rufus.*

In one species we have the following arrangement :—

Ex. secundus, } From the
Ex. indicis, } ulna.

Ex. Medius, } From the
Ex. annularis, } external
Ex. minimus, } condyle.

Hynœa crocuta (no secundus). | *Sciurus maximus.*
Raccoon cancrivorus. | *Meles taxus.*
Lutra vulgaris (indicis bifurcates to furnish secundus tendon).

A similar arrangement is present in some of the metatheria, including—

Phascolarctos cinerus. | *Cuscus maculata.*

Among other mammals dissected for this purpose were—

Hyrax capensis. | *Perameles lagotis.*

In most of these the minimus and annularis were present, arising from the ex. condyle, but one or all of the remainder were wanting. Most of the Quadrumana present these muscles arranged as follows :—

Ex. secundus,
Ex. indicis,
Ex. medius, { Discrete muscles arising from the dorsal aspect of the ulna.

Ex. minimus, } From the ex-
Ex. annularis, } ternal condyle.

This arrangement occurs in the following species—

Macacus cynomolgus.
   ,,   *sinicus.*
   ,,   *callitrichus.*
Procarius cynocephalus.
Brachyurus rubicundus.

Cercopithecus cynosurus.
   ,,   *petaurista.*
Cercocebus coollaris.
Cercocebus albigena.
Nyctipethecus vociferans.

Lemur catta. | *Perodicticus potto.*

A great deal of labour has been spared me by the timely appearance of a short but very useful paper by Professor Windle, read before the Birmingham Philosophical Society, entitled " A Note on the Extensor Tendon of the Manus of Apes." Many of the species dissected by Professor Windle have also been examined by me, and the independent dissections correspond in

a˜satisfactory way. Our investigations, however, though embracing much the same material, so far as the Quadrumana were concerned, differ in an important· particular. Professor Windle examined his material from a purely anatomical standpoint, whereas my dissections were conducted for the purpose of interpretation. In this way the Professor's disinterested inquiry has been very welcome to me, and I would refer my readers to it for details not given here.

The Pyramidalis Muscle.

No scientific anatomist will deny that the pyramidalis is a vestigial muscle. When developed to its fullest condition in man, it may reach to the umbilicus; this is, however, very exceptional. Usually it is a small muscle, resting on the lower part of the rectus. It arises from the front of the pubis and the ligaments of the symphysis; assuming a pointed shape, it passes upwards to be inserted into the linea alba, midway between the symphysis and umbilicus. Most anatomists will agree with Testut in considering the pyramidalis as one of the most inconstant of muscles in man. This inconstancy is sufficient to show that it is of secondary importance. One or both muscles may be absent, or represented by fibrous tissue. Occasionally the muscles may be scarcely half an inch in length. In rare cases two superimposed pyramidales have been seen on each side. Among mammals the pyramidalis attains its greatest proportions among the metatheria (Marsupialia); it is exceptionally developed in Ornithorhynchus. In the kangaroos this muscle arises from the ventral aspect of the symphysis pubis, and from the contiguous surface of the pubic ramus as far outward as the pectineal process; it also has a large and important origin from the median border of the epipubes (marsupial bones). The fibres of the muscle are closely connected with the ventral wall of the marsupium, and pass forwards immediately in contact with the rectis abdominis, to be inserted into dense tissue over the costal cartilages of the most posterior ribs and the scyphoid. On its way along the abdomen we find it blending with its fellow, to form with the rectus the linea alba.

If the connections of the epipubic bones be closely examined, we find, as represented in the accompanying drawing (fig. 1),

that each bone is firmly bound to the horizontal ramus of the pubes by a very strong and dense fascia. This fascia is attached to the ilio-pectineal line, and closely associated with Poupart's ligament, whilst above it is inserted to the whole length of the outer border of the epipubic bone.

Fig. 1.—Pelvis of *Macropus rufus.* Ventral view to show the pyramidalis arising from the epipubis.

If we compare the corresponding parts of man's pubic region with that of the kangaroo, we find the internal pillar of the external abdominal ring representing the epipubic bone, and two well-marked fibrous structures known as *Gimbernat's ligament and the triangular fascia.* These two structures are not only directly continuous with each other, but are intimately related to the internal pillar of the abdominal ring. Some careful dissections of these fasciæ, compared with dissections of the corresponding parts in the marsupials, make me bold enough to state that Gimbernat's ligament and the triangular fascia are remnants of the very stout ligament which, in marsupials,

anchors the epipubic bone firmly to the ilio-pectineal line. Whether this fascia was muscular or not in the ancestors of the kangaroos it is difficult to decide, but, judging from the anatomy of the superficial rectus abdominis in the salamander, most probably it was. In *Ornithorhynchus* the ligament is very small, and the epipubic bone extends as far outward as the ilio-pectineal eminence. There need be little hesitation in accepting this interpretation of the nature of the triangular fascia and Gimbernat's ligament, when we remember that there is a concensus of opinion among anatomists in regarding the internal pillar of the abdominal ring as the homologue of the epipubic bone.

It is also a point of considerable interest to find in man this relation of fascia, ligament, and internal pillar to each other, for the regression of the large metatherial pyramidalis muscle stands in close relation to the degeneration of the epipubis and disappearance of the marsupium. Neither must the comparatively large development of the ilio-pectineal process in the kangaroos, especially in embryos, be forgotten.

To many it may seem strange to associate these parts of most mammals with those of marsupials now practically confined to the Australian continent. But we must remember that, in former periods of this planet's history, our own island was inhabited by marsupial forms of large size and in goodly numbers, judging from the fossil remains which from time to time have come to light. Their former wide dissemination is a point not to be forgotten.

The Scansorius (Gluteus Quartus).

In 1818 Dr Traill,[1] in a paper entitled "Observations on the Anatomy of the Chimpanzee," makes the following remarks in his description of the myology of this mammal:—

"The most remarkable muscle about the top of the thigh has not been noticed by Tyson, Camper, Cuvier, or the older anatomists. It is a flat triangular muscle arising from the whole anterior edge of the ilium to within half an inch of the acetabulum, and is inserted to just below the fore part of the great trochanter, between the head of the cruralis and the vastus externus, a little below the origin of the

[1] *Wernerian Transactions*, vol. iii. It was really an Orang.

former; it is thin and fleshy throughout its whole extent, except where it is inserted by a very short, flattened tendon. At its upper part it is united by cellular substance to the iliacus internus. The action of the muscle, which appears to be peculiar to this animal, is to draw the thigh upwards towards the body; and it seems especially intended to assist in climbing. On this account we propose to call it the *scandens* or *musculus scansorius*, and we are disposed to regard this as one of the principal peculiarities of the muscle."

The account given by Traill accords in every particular with the condition of the muscle in two specimens of chimpanzee which I dissected, with a special eye to their myology. Owen[1] refers to it briefly as the "invertor femoris." It has been my custom to regard this muscle as the representative in the chimpanzee of the tensor vaginæ femoris of man. In 1883[2] I ventured to regard the scansorius of Traill and the tensor

FIG. 2.—The Gluteus quartus (scansorius) in man.   (After Gruber.)

vaginæ femoris as one and the same muscle. Subsequent study and reading have served to convince me that such an opinion is clearly erroneous. My attention was more forcibly directed to this matter in consequence of a communication made by Gruber in Virchow's *Archiv*, Bd. cvii. S. 480, in which he describes two cases of the occurrence of a scansorius under the name of gluteus quartus in man. The shape, disposition, and attachment of this muscle is well shown in fig. 2, taken from Gruber's memoir.

[1] *Anatomy of Vertebrates*, vol. iii. p. 54.
[2] "Some Points in the Anatomy of the Chimpanzee," *Journal of Anatomy and Physiology*, vol. xviii.

The muscle arose from the ilium near the anterior superior spine, in close relation with the gluteus minimus, but is quite distinct from it, and passes to the outer surface of the great trochanter, slightly posterior to the tendon of insertion of the gluteus minimus. In both cases Gruber states precisely that it was an independent muscle, and not a detached portion of the gluteus minimus or medius. Gruber further refers to his examination of some fifty mammals, with regard to the existence, degree of development, and homology of this muscle.

Testut has given an excellent account of this muscle in his comprehensive work, *Les Anomalies Musculaires chez l'homme*, p. 598, and shows that it has attracted the attention of a considerable number of anatomists.

Seeing that the gluteus quartus occurs as a well-developed muscle in a very large number of the Mammalia, is especially well developed in Quadrumana, and occasionally occurs as a well-differentiated muscle in man, it seemed possible that a careful search about the human hip-joint might bring to light some fibrous representative of this muscle. Before doing so, I made a careful dissection of the gluteus quartus in several Quadrumana in order to ascertain its relation to the capsule and the tendon of the rectus femoris muscle. A comparison of the hip-joint in man and Quadrumana brings out one point very strongly. The various bands known as accessory ligaments of the capsule seem to be peculiarly human, and the reflected tendon of the rectus which, in man, lies in the layers of the capsule, in other mammals is quite outside this structure.

In mammals possessing a gluteus quartus, the muscle fibres, which arise from the ilium near the anterior inferior spine, overlap the reflected tendon of the rectus femoris, and bear precisely the same relation to it as the fibrous expansion in the capsule of man's hip-joint. Pursuing the matter still closer, we find that the limb of what is known as the ilio-femoral band, which is associated with the great trochanter and anterior inferior spine of the ilium, corresponds in attachment, relation to the gluteus minimus, and reflected tendon of the rectus, to the origin and insertion of the gluteus quartus.

Further, the ilio-femoral band is by no means a constant structure. When fully developed it is rounded and tendon-like,

at other times it simply appears as a slight thickening in the capsule; on the other hand, it may be unrepresented. Its attachments are shown in fig. 3.

The gluteus quartus presents itself in a variety of forms. In many mammals it lies between the gluteus medius and minimus. In others the muscle is in actual contact with the capsule of the hip-joint. It also appears to be correlated with the degree of development of the gluteus minimus. When this muscle is large, the gluteus quartus is merely a narrow muscular

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FIG. 3.—The Hip-Joint of Man, showing the ilio-femoral band (gluteus quartus). (After Henry Morris.)

slip. In some cases, when the gluteus minimus is relatively small, the gluteus quartus may nearly equal it in size. In all cases in which I have been able to determine the nerve supply, it was derived from the superior gluteal.

In *Cercocebus collaris* I found the gluteus quartus absent, but its place was occupied by a well-developed band of ligamentous tissue resting upon the capsule of the joint, covering the reflected tendon of the rectus femoris, and attached below to the great trochanter. This is very significant.

A full consideration of these facts induces me to venture the

opinion that *the outer limb of the ilio-femoral band is the fibrous representative of the gluteus quartus* (scansorius) *muscle.*

The argument may be arranged in a convenient form :—

1. The ilio-femoral ligament corresponds in its attachments to the gluteus quartus muscle.
2. The relation of the ligament to the reflected tendon of the rectus femoris muscle is precisely that exhibited by the gluteus quartus in most mammals.
3. In at least one monkey, *Cercocebus collaris*, the ilio-femoral band is present, but no gluteus quartus.
4. In other monkeys possessing a functional gluteus quartus, the ilio-femoral band is unrepresented.

For the sake of completeness I have appended a list of mammals which possess this muscle in a functional condition.

(Those indicated by an asterisk are from my own dissections.)

Homo sapiens.	Hylobates leuciscus.
Chimpanzee.	Cercopithecus cynosurus.
Macacus radiatus.	Nyctipithecus vociferans.*
Cebus apella.	Hapale penicillata.
Felis leo.	Ursus labiatus.
Ursus maritimus.*	Meles taxus.*
Ursus arctos.	
Mus rattus.*	Phalangista.*
Dasyprocta aguti.*	Hypsyprymnus.*
Perameles lagotis.*	Phascolomys wombat.*
Cheiromys madagascarensis.*	Pteromys volans.*
Bradypus tridactylus.*	Cavia aperea.*
	„ cobaya.*

In the series of papers which I have from time to time published on the question of the "Nature of Ligaments," my aim has been to record the dissections on which the interpretations have been founded. It will surely follow that others will naturally put a different interpretation, in some of the cases, to that adopted by me. It must, however, be understood that I am not so anxious to prove that in all the particular cases dealt with the true explanation has been offered, but my most anxious

endeavour throughout has been to establish a principle regarding the origin of many remarkable ligamentous structures strewn throughout our bodies.

In my experience as a teacher, the marked and eager attention displayed by a class of students to morphological explanations of apparently insignificant bands of fibrous tissue, aponeurotic tracts and expansions, is a satisfaction inexpressible.

COMPARISON OF THE CONVOLUTIONS OF THE SEALS AND WALRUS WITH THOSE OF THE CARNIVORA, AND OF APES AND MAN. By Professor Sir W. TURNER, Knt., M.B., LL.D., F.R.S.

IN my Report on the Seals collected during the voyage of H.M.S. "Challenger" (*Zool. Chall. Exp.*, part lxviii., 1888), I have written a chapter descriptive of the brain of the Elephant Seal (*Macrorhinus leoninus*) and of the Walrus (*Trichechus rosmarus*), and have figured the brains of these animals. In connection with that description I have compared the arrangement of the convolutions in the Seals and Walrus with that found in the Carnivora proper and in Apes and Man. As the facts described and the opinions expressed in the course of this comparison may perhaps be of interest to the readers of this *Journal*, I have reproduced them here.

M. Leurct, in his well known *Anatomie comparée du Système Nerveux*,[1] both figures and describes the cranial surface of the brain of a Seal, probably *Phoca vitulina*. He considers that the convolutions in this animal are analogous to those of the Ungulata, especially the Pig, though without resembling them throughout; and in his arrangement of the Mammalia, according to the grouping of their convolutions, he places the Ungulata, Edentata, and Marsupialia between the Carnivora and the Seals. He recognises only three convolutions in the hemisphere of the Seal—one *internal*, on the inner surface, which is obviously the gyrus fornicatus or great limbic lobe of Broca;[2] one *external*, bounding the fissure of Sylvius and very irregular; one *superior*, extending from before backwards on the top of the hemisphere and forming two tiers, with two subdivisions in front and three behind, while he regards the supraorbital convolution as only an offshoot of the two anterior subdivisions. Sir Richard Owen,[3] again, has recognised

[1] Paris, 1839–1857.
[2] *Revue d'Anthropologie*, sér. 2, t. i., 1878.
[3] *Comparative Anatomy of Vertebrates*, vol. iii., 1868.

in the brain of *Phoca* a prefrontal lobe in front of the frontal crucial fissure; an orbital fold above the orbit; Sylvian, super-sylvian, medilateral, and medial folds or convolutions arranged in tiers above the fissure of Sylvius. It is obvious, however, from his diagram of the outer surface of the hemisphere (fig. 93, p. 118), that he does not consider the interval of separation between the medial and medilateral folds to be as definite as those between the other convolutions on the same surface. Krueg,[1] who has also studied the brain of *Phoca vitulina*, devotes his description to an account of the fissures, and does not even name the convolutions. It would seem, however, both from. his description of the fissures and accompanying figures of the brain, that he only recognises three tiers of convolutions on the outer surface of the hemisphere, whilst a well-marked splenial fissure on the inner surface individualises the hippocampal and callosal convolutions. Paul Broca's account of the brain of a *Phoca* is principally taken up with a description of the great limbic lobe, and its relation to the olfactory apparatus.

In the brain of *Phoca vitulina*, two specimens of which I have dissected, I found on the outer surface of the hemisphere a distinct fissure of Sylvius, with its Sylvian convolution, the anterior limb of which was narrower than the posterior, and at its commencement concealed within the fissure of Sylvius. When this fissure was widely opened out, prolongations of the Sylvian convolution were traced deeply into it, and occupied the position of an insula. Above the Sylvian convolution were a suprasylvian fissure and convolution, the latter of which showed at its summit a disposition to subdivide into two parallel gyri for a short distance. This convolution was bounded above by a lateral fissure, between which and the mesial longitudinal fissure were two slender convolutions running antero-posteriorly; the lateral of these was apparently the mediolateral convolution, whilst the medial one bounded the longitudinal fissure and was the sagittal convolution; as in Owen's figure, however, the fissure which separated the sagittal (medial) from the mediolateral convolution was not continuous, but was bridged by short annectent gyri. As this mediolateral fissure was imperfect and not prolonged far forward in front, the coronal fissure was not continuous with it. In one instance the coronal was prolonged backwards into the lateral fissure, but it might be separated from it by an intermediate bridging convolution. In this region, therefore, the brain of *Phoca vitulina* closely corresponded in the arrangement both of convolutions and fissures with the Elephant Seal, though in the latter, from its greater size, the con-

[1] *Zeitsch. f. wiss. Zool.*, Bd. xxxiii., 1880.

volutions were bigger, also I think more tortuous, and certainly with a greater number of bridging convolutions.

In the Walrus, again, the four tiers of convolutions were more definitely expressed on the outer surface of the hemisphere, partly owing to the comparative absence of bridging convolutions, and partly because the mediolateral fissure formed a definite plane of separation between the sagittal (medial) and mediolateral convolutions. In this animal also the anterior limb of the Sylvian convolution was narrower, and sunken into the fissure of Sylvius much more than either in *Phoca* or *Macrorhinus*, and from Dr Murie's description and plate of the brain of *Otaria jubata*[1] (fig. 40) it is obvious that a corresponding depression occurred also in that of the Eared Seal. This narrowing and depression were more marked than in Leuret's figures of the Brown Bear, Coati, and Otter in pl. vi. of his *Atlas*. But I find that in the brain of an Otter (*Lutra vulgaris*), of the Badger (*Meles taxus*), and Ratel (*Mellivora indica*) in the University Museum a similar sunken condition of this limb of the Sylvian convolution exists.

From the examination of these brains of *Trichechus*, *Phoca*, and *Macrorhinus*, I am disposed to regard these animals as more or less approximating in the arrangement of the convolutions of the outer face of the hemisphere to those Carnivora which possess four tiers of convolutions in relation to the fissure of Sylvius. This arrangement is found in the Dog, Jackal, Fox, and Wolf.[2] From Dr Murie's figures of the brain of *Otaria jubata* it would appear that in that animal, whilst the Sylvian and suprasylvian convolutions are quite definite, yet that the subdivision of the marginal convolution of the longitudinal fissure into mediosagittal and mediolateral convolutions is so partial that the arrangement seems to be intermediate to that which one finds in *Trichechus* and the Canidæ on the one hand, and in the Cats on the other. In regarding this affinity in the general arrangement of the convolutions of the cranial surface of the hemisphere in the Seals with those of the Canidæ, it must be kept in mind that in the Dogs the convolutions are less tortuous, and with fewer secondary fissures and gyri than in the Pinnipedia.

The hemisphere of the cerebrum of *Phoca vitulina* possessed on the mesial and tentorial surfaces a distinct gyrus fornicatus or great limbic lobe, which was divided into uncinate, hippocampal and callosal convolutions, and was differentiated on its peripheral side by the splenial fissure or the limbic fissure of Broca. This fissure was bridged in its posterior part by a short retrolimbic gyrus, the *pli de passage retrolimbique* of Broca. The splenial fissure had not always the same termination at the upper and anterior end, for in the same brain I have seen it prolonged forwards into the crucial fissure in one hemisphere, but in the other separated from it by a bridging convolution. Both the suprasplenial convolution and fissure existed in the region above the corpus callosum, though in one hemisphere the fissure was bridged by a short gyrus. Neither the postsplenial fissure

[1] *Trans. Zool. Soc. Lond.*, vol. viii., 1874.
[2] See pl. iv. in Leuret's and Gratiolet's *Atlas*.

nor the splenial convolution was distinctly differentiated, and the tentorial surface was subdivided into narrow convolutions. At its inferior end the splenial fissure was continuous with the postrhinal fissure, and through it with the transverse part of the fissure of Sylvius, across which it was prolonged into the rhinal fissure, which defined the tuber olfactorium externally. The tuber was distinctly prolonged into the uncinate gyrus across the bottom of the fissure of Sylvius. Immediately to the outside of the connecting band between the tuber and uncinate gyrus was the concealed portion of the anterior limb of the Sylvian convolution, which apparently represented the Island of Reil. The supraorbital area possessed a gyrus rectus, olfactory fissure, intraorbital fissure, internal and external supraorbital convolutions. The olfactory peduncle was very slender, more so indeed than would be imagined from the figures published by Tiedemann[1] and Leuret. The crucial fissure was at the anterior end of the hemisphere, and about 14 mm. in its transverse diameter, and had the usual relation to the sigmoid gyrus, with which the sagittal convolution was continuous. No præcruciate fissure could be seen on the cranial surface of the cerebrum, but, when the hemispheres were separated from each other, a short fissure was recognised passing downwards from the crucial fissure, which apparently was the præcruciate fissure, whilst the short convolution which it differentiated represented the ursine lozenge, situated as Mivart has stated entirely on the mesial surface of the hemisphere. The prorean convolution was continued into the gyrus rectus.

The convolutions and sulci on the inner and tentorial surface of the hemisphere of *Macrorhinus* corresponded in essential particulars with those of *Phoca*. Some differences are, however, to be noted. Thus in *Macrorhinus* the splenial fissure was not continuous with the postrhinal fissure, neither was it bridged across superficially by a retrolimbic pli-de-passage, though there was a short gyrus projecting backwards from the hippocampal convolution which may represent it. In both hemispheres the splenial fissure was continued into the crucial fissure; the demarcation of the splenial from the sagittal convolution by a continuous antero-posterior suprasplenial fissure was less marked in *Macrorhinus* than in *Phoca*.

In the Walrus, also, the splenial and postrhinal fissures were not continuous with each other. In one brain there was no retrolimbic bridging convolution, which was present however in both hemispheres of another specimen, and in one of these hemispheres was represented by two convolutions. In two brains the splenial fissure joined anteriorly the crucial fissure. The definition of the suprasplenial convolution and fissure varied in opposite hemispheres. Both brains possessed postero-horizontal and postsplenial fissures and a splenial convolution. The olfactory peduncle and bulb were larger than in the Phocidæ.

In *Otaria jubata*, if I may judge from Dr Murie's drawings of the brain of that animal, the postrhinal and splenial fissures were not continuous with each other; the splenial fissure was bridged by a retro-

[1] *Icones Cerebri*, Heidelberg, 1821.

limbic convolution; the splenial fissure was not prolonged directly into the crucial fissure; the suprasplenial convolution and fissure were not sharply differentiated; the olfactory apparatus was more like in size the same parts in the Walrus than in the Phocidæ.

Dr St George Mivart has recently introduced [1] into the study of the brain in the Carnivora and Pinnipedia the consideration of the area which he has named the Ursine lozenge, and has pointed out that it constitutes a well-marked feature in the anterior part of the dorsal surface of the cerebrum of *Otaria gillespii*. In both *Phoca* and *Macrorhinus*, but especially in the former, this area was rudimentary, and concealed in the mesial fissure of the cerebrum. In the Walrus, again, the single convolution which represents this area was not definitely defined. Dr Mivart attaches much importance to the presence of the ursine lozenge in the Pinnipedia, as indicating phylogenetic relations to the ursine group of the Carnivora.

I shall now compare the convolutions on the mesial and tentorial surfaces of the hemisphere in the Pinnipedia with the corresponding surfaces in the brains of several of the Canidæ, and the brains which I have examined are those of the Dog, Jackal, and Fox. In all these animals the postrhinal fissure joined the splenial fissure as in *Phoca vitulina*. The splenial fissure on the tentorial surface was not bridged superficially by a retrolimbic convolution. The lobus and the hippocampal and callosal divisions of the gyrus fornicatus were definitely expressed. The splenial fissure was continued at its anterior end into the crucial fissure, which was placed in the anterior third of the dorsum of the hemisphere. In none of these brains was a suprasplenial convolution differentiated from the sagittal convolution by a suprasplenial fissure, though in the Dog's brain an indication of such a fissure was present. The crucial fissure was bounded by the sigmoid gyrus, which was continuous with the sagittal convolution. Immediately external to the sigmoid gyrus was the coronal fissure, which was continued backwards into the mediolateral fissure, but not forwards into the præsylvian fissure. There was neither præcruciate fissure nor ursine lozenge. The olfactory peduncle was both relatively and absolutely larger than in the Seals and Walrus notwithstanding the much smaller brain, and the continuity of its large root with the lobus hippocampi was plainly marked across the fissure of Sylvius.

In the Polar Bear (*Ursus maritimus*) the postrhinal fissure was deep, and passed back towards the splenial fissure, but was separated from it by a slender retrolimbic gyrus partially sunk in the fissure. The anterior end of the splenial fissure was not continuous with the crucial fissure, but bifurcated; the posterior branch reached the dorsum of the hemisphere as a sulcus in the ursine lozenge, the anterior passed horizontally forwards in front of the knee-like bend of the callosal convolution. The suprasplenial was not differentiated from the sagittal convolution by a suprasplenial fissure, although there was an indication of such a fissure posteriorly. The tentorial surface possessed both a postsplenial fissure and a splenial convolution.

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[1] *Jour. Linn. Soc. London* (Zoology), vol. xix., 1884.

The ursine lozenge was large, being 34 mm. long by 42 mm. wide. It formed a large proportion of the anterior third of the dorsum of the hemispheres, and was partially intersected by small sulci, one of which was the posterior branch of bifurcation of the splenial fissure. The crucial fissure was 40 mm. long. The sigmoid gyrus which enclosed it was strongly developed, and its posterior limb was continuous with the sagittal convolution. The coronal fissure was behind and to the outer side of the posterior limb of the sigmoid gyrus, and was prolonged backwards into the 1st curved fissure, but not forwards into the præsylvian fissure. The Polar Bear had three distinct convolutions above the Sylvian fissure. It seemed at first as if they represented the Sylvian, suprasylvian, and marginal convolutions, and as the last named was partially divided by an antero-posterior fissure into two, it looked as if it might represent both the sagittal and the mediolateral convolutions of the Dog and Walrus. On opening up the Sylvian fissure I found to my surprise that a definite arched convolution was completely concealed within it. It was separated from the convolution which bounded the Sylvian fissure by a deep fissure which was also concealed. Its anterior limb, not quite so bulky as the posterior, was continued into the supraorbital area immediately external to the rhinal fissure, and to the outer root of the olfactory peduncle. Its posterior limb reached the postrhinal fissure and the lobus hippocampi. I could not but think that we had here, more completely than either in the Walrus or Seals, a sinking into the Sylvian fissure of the convolution which ought to have bounded it, so that both the Sylvian convolution properly so called, and the suprasylvian fissure, were concealed within it. If this be a proper explanation of the arrangement, then the three convolutions on the cranial aspect would be sagittal, mediolateral, and suprasylvian; whilst the two complete curved fissures between them would be the mediolateral and lateral. The 1st curved fissure therefore into which the coronal fissure is prolonged, would then, as in the Dog, be the mediolateral fissure. The olfactory apparatus was large, and the external root formed a thick broad band of connection with the lobus hippocampi, so that the Sylvian fossa was shallow.

In the Badger (*Meles taxus*) the postrhinal fissure was deep and prolonged towards the splenial fissure, from which it was separated by a short retrolimbic gyrus; anteriorly the splenial fissure was continuous with the crucial fissure; a short præcruciate fissure marked off a small ursine lozenge, consisting of a single convolution, and situated about the junction of the anterior and middle third of the dorsum of the hemisphere. The suprasplenial was not differentiated from the sagittal convolution. The crucial fissure was 18 mm. long, and bounded by a relatively large sigmoid gyrus, the posterior limb of which was continuous with the sagittal convolution. Below and behind the sigmoid gyrus was the coronal fissure, which was continued backwards into the 1st curved fissure, but not forwards into the præsylvian fissure. Only three convolutions surmounted the Sylvian fissure, the anterior limb of the Sylvian convolution was partly concealed in that fissure, the suprasylvian and marginal convolutions

were distinct, and the latter was not divided into a sagittal and a mediolateral convolution. The olfactory apparatus was large.

In the Ratel (*Mellivora indica*) the postrhinal fissure was deep and separated from the splenial fissure by a short and partially concealed retrolimbic gyrus. The callosal convolution was relatively wide, and closely resembled in its proportion the corresponding convolution in the Otter as figured by Broca (*op. cit.*, fig, 1, p. 399). The splenial fissure terminated a little in front of the middle of the dorsal surface of the hemisphere in the crucial fissure ; a short præcruciate fissure was also present, and between it and the crucial fissure was a distinct ursine lozenge formed of a single convolution.[1] The marginal convolution was very narrow, and the suprasplenial convolution and fissure were absent, though it is possible that this convolution was potentially present in the callosal convolution. The crucial fissure was 17 mm. long, and enclosed by a broad sigmoid gyrus which was continuous by its posterior limb with the marginal gyrus. The coronal fissure which bounded it was prolonged backwards into the 1st curved fissure, but not forwards into the præsylvian fissure. Well-defined Sylvian and suprasylvian convolutions were present, but only a slight indication of a division of the marginal convolution into sagittal and mediolateral convolutions was visible. No arched convolution was concealed within the Sylvian fissure. The olfactory apparatus was large.

My dissection of the inner and tentorial surface of the hemisphere of the Otter (*Lutra vulgaris*) closely accords with Paul Broca's figures and description. In this animal the crucial fissure was 14 mm. long ; the sigmoid gyrus was relatively large ; the coronal fissure was not continuous with the præsylvian fissure ; Sylvian, suprasylvian, and marginal convolutions were present ; the anterior limb of the Sylvian was almost entirely concealed in the fissure, and there was evidence of separation of the marginal convolution into sagittal and mediolateral by a short mediolateral fissure which was interrupted ; but the coronal fissure should be regarded as prolonged into the fissure bounding the upper aspect of the suprasylvian convolution, which may therefore be termed lateral.

In the Coati (*Nasua rufa*) the postrhinal was separated from the splenial fissure by a short retrolimbic gyrus; the splenial did not join the crucial fissure, but terminated behind it in a sulcus in the sagittal convolution, which did not reach the margin of the hemisphere. The marginal part of the sagittal convolution was relatively wider than in the Otter and Ratel. The crucial fissure was distinct, but, owing to an injury to this part of the brain, I could not speak with certainty of the presence of a præcruciate fissure leading forwards and inwards from the crucial fissure ; a small convolution in front of the crucial fissure apparently represented the ursine lozenge,

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[1] Figures of the ursine lozenge in the brains of *Ursus maritimus* and *Mellivora indica* have been given by St George Mivart in his memoir already quoted, and its presence in the brains of the Otter, Badger, Coati, and other Arctoid Carnivora is described by him.

a convolution which Mivart also considers to exist in the brain of this animal. Only three tiers of convolutions were present.

In the Weasel (*Mustela vulgaris*) the postrhinal fissure was separated from the splenial by a retrolimbic gyrus which was broad in relation to the size of the hemisphere. The splenial fissure ended in the crucial fissure on the dorsum of the hemisphere. No præcruciate fissure was visible on the dorsum, but on opening up the crucial fissure a very short sulcus indented the convolution which formed the boundary of the crucial fissure and marked off the anterior boundary of a minute ursine lozenge. In the Ferret (*Mustela furo*), however, a short but distinct præcruciate fissure differentiated the anterior boundary of a minute ursine lozenge. The splenial fissure ended in the crucial fissure on the dorsum of the hemisphere. The splenial was separated behind from the postrhinal fissure by a short retrolimbic gyrus. In both the Weasel and Ferret the marginal part of the sagittal convolution was much narrower than the callosal convolution. In both, also, the olfactory apparatus was largely developed. In the Coati, Weasel, and Ferret the relations of the sigmoid gyrus to the coronal fissure, and of that fissure to the 1st curved fissure, closely corresponded to the arrangement in the Badger and Ratel.

I have examined in the Felidæ the tentorial and mesial surfaces of the hemisphere in the brains of the common Cat (*Felis domesticus*) and the Tiger (*Felis tigris*). In the Cat one retrolimbic gyrus, and in the Tiger two, separated the splenial from the postrhinal fissure, and in the latter a third bridging convolution crossed the splenial fissure immediately behind and above the splenium. In both, the crucial fissure was situated in the anterior part of the dorsum of the hemisphere, and was not joined by the splenial fissure, which in both animals reached the margin of the hemisphere behind the crucial fissure. In neither animal was there an ursine lozenge. In the Tiger the convolutions were more subdivided by secondary fissures than in the Cat, and on the tentorial surface both a postsplenial fissure and a splenial convolution were present. Both animals had a large olfactory apparatus connected by a strong tract with the uncinate convolution.

In the common Cat the coronal fissure was short and cut off by an intermediate narrow gyrus from the præsylvian fissure in front and the 1st curved fissure behind; it bounded the sigmoid gyrus externally. In the Tiger, in which the sigmoid gyrus was large and tortuous, the coronal fissure formed its outer boundary, and though not prolonged forward into the præsylvian fissure, it was continued backwards into the 1st curved fissure. In both the Cat and Tiger the sagittal convolution was continuous with the posterior limb of the sigmoid gyrus.

It is well known that in the Felidæ the differentiation of the convolutions on the cranial surface of the hemisphere into four tiers is not so precise as in the Canidæ. The convolution which bounds the Sylvian fissure is, in all probability, homologous in both families. In the Tiger the suprasylvian convolution was differentiated in its whole length from the Sylvian convolution by the suprasylvian

fissure, and from the sigmoid gyrus and sagittal convolution by the 1st curved fissure.   There was no distinct mediolateral convolution, but a convolution which might represent it was partially differentiated from the sagittal convolution by an imperfect mediolateral fissure. In the common Cat the sagittal and the 2nd external convolution were distinctly differentiated from each other by an intermediate fissure, but the Sylvian and suprasylvian convolutions were partially blended together, especially in their posterior limbs.

In the series of brains examined the coronal fissure was seldom continued forward into the praesylvian fissure, but it was very frequently prolonged backwards into one of the curved fissures on the cranial aspect of the hemisphere,[1] though sometimes it was interrupted by a short bridging convolution.   When prolonged into a fissure it joined that which lay next to the marginal convolution or the 1st curved fissure.   But this was not necessarily morphologically the same in all these brains.   Where four tiers of convolutions were differentiated, it was, of course, the mediolateral fissure, but when only three tiers were differentiated, then it probably represented the lateral fissure, as in these brains both the mediolateral fissure and convolution were either absent or only imperfectly differentiated. The coronal fissure formed the outer boundary of the sigmoid gyrus. The coronal gyrus was the anterior part of the 2nd external convolution, which in those brains that possessed four tiers of convolutions was the mediolateral convolution; but, when only three tiers were present, it was most probably represented by the suprasylvian convolution.

The crucial fissure varied materially in its position in the genera of the Carnivora and Pinnipedia.   In the Seals and Walrus it was so far forward as not to be seen on the dorsum of the hemispheres, but only at the anterior end of the cerebrum.   In the Cat and Tiger it was visible in about the anterior fourth of the dorsum of the hemispheres; in the Dog, Weasel, Ferret, and Coati at about the junction of the middle and anterior third; in the Badger, Polar Bear, and Ratel it was even farther back, so as to be just in front of a line dividing the dorsum of the hemispheres into an anterior and a posterior half.   This variation in the position of the fissure necessarily affected that of the sigmoid gyrus which bounded it in front, behind, and on the outer side, and in those brains in which the fissure was elongated and far back this gyrus formed a well-marked convolution on the dorsum of each hemisphere.   When the crucial fissure was elongated, both it and the sigmoid gyrus were continued downwards on the outer surface of the hemisphere,[2] and the direction of the

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[1] In Leuret's figure of the brain of the Lion, the coronal fissure is continuous with the 1st curved fissure, but in Victoria Familiant's figure of the brain of this animal (*Vergleichung der Hirnfurchen bei den Carnivoren und den Primaten*, Bern, 1885) these fissures are separated from each other, as in the common Cat, by an intermediate bridging convolution.

[2] The anterior limb of the sigmoid gyrus is sometimes called *gyrus praecruciatus* (*praefrontalis*), the posterior limb *gyrus postcruciatus* (*postfrontalis*).

coronal fissure, which formed the outer boundary of the sigmoid gyrus, was from below obliquely upwards and backwards.

It will now be of interest to compare the convolutions of the cerebrum in the Carnivora and Pinnipedia with those in Man and Apes, with the view of endeavouring to ascertain if any correspondence in their arrangement exists, and to what extent, in these orders of Mammals. The importance of instituting this comparison has already, indeed, presented itself to several anatomists, and various attempts have been made to harmonise the arrangement of the convolutions of the Carnivora with those of Man and Apes. The desirability of arriving at some definite conclusion on this matter is owing both to the interest of the subject from a purely morphological point of view, and to its physiological value in connection with the numerous experiments which have of late years been made for the determination of the functions of the cerebral cortex.

It will be obvious, if in the brains of these different orders one or two leading fissures and convolutions can be identified as without question morphologically alike in their development and relations, that a certain basis would be obtained from which it may be possible to extend the comparison to other parts of the surface. A most important investigation conducted in accordance with this method was published by Dr Paul Broca, on " Le Grand Lobe Limbique et la Scissure Limbique."[1] In the course of this memoir he reviewed the arrangement of the limbic lobe or convolution, and showed that it can be identified throughout the mammalian series. It consists of a callosal and hippocampal portion with a lobus hippocampi, and forms the boundary both of the corpus callosum and the transverse fissure of the cerebrum. Moreover, it is continuous with the roots of the olfactory lobe, more especially through the lobus hippocampi, though the band of union varies materially in thickness in the brains of different orders. In the proper Carnivora, for example, the connecting band is large and very distinct, in the Pinnipedia it is less marked, and in Man and Apes it is reduced to a fine thread.

In the Carnivora proper the rhinal fissure is distinct and continued across the fissure of Sylvius into the postrhinal

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[1] See *Revue d'Anthropologie*, op. cit.

fissure, which again is prolonged towards the splenial fissure, though frequently the exact continuity is interrupted by a superficial retrolimbic convolution. In *Phoca* the rhinal and postrhinal fissures resemble those in the Carnivora proper, though relatively they are somewhat smaller. In *Macrorhinus* and *Trichechus* the retrolimbic convolution is nearer the lobus hippocampi, so that the postrhinal fissure is shorter. In Man and Apes, owing to the absolute and relative diminution in size of the olfactory apparatus, the rhinal fissure is scarcely recognisable, and the postrhinal fissure cannot be said to be continuous with it.

The limbic lobe is differentiated on its peripheral aspect by the fissure which has been named the splenial fissure in the brains of the Carnivora and Pinnipedia described in this memoir. In Man and Apes the calloso-marginal fissure represents that part of the splenial fissure placed peripherally to the callosal convolution, whilst the collateral (occipito-temporal) fissure is apparently the representative of that part of the splenial fissure which forms the peripheral boundary of the hippocampal convolution.

In the larger Carnivora and the Pinnipedia the supraorbital area possesses an olfactory sulcus, a gyrus rectus, an intraorbital fissure, internal and external supraorbital convolutions; though in the brains of the smaller Carnivora, especially when the olfactory apparatus is relatively large, these fissures and convolutions are scarcely if at all differentiated. In Man and Apes these parts are also seen, and the intraorbital fissure, from so frequently trifurcating, was named by me the triradiate fissure.

The fissure of Sylvius forms a recognisable feature in the brains of the Carnivora, but where it begins as the Sylvian fossa on the under surface of the brain, it is usually shallow, owing to the thickness of the olfactory root which passes backwards to join the lobus hippocampi. In the Pinnipedia, and still more in Man and Apes, owing to the diminished size of this root, the Sylvian fossa is much deeper. In the Carnivora and Pinnipedia the fissure of Sylvius passes upwards and with only a slight inclination backwards on the cranial surface of the hemisphere, its length being regulated by the length of the Sylvian convolution which bounds it. In Man and Apes, more especially the Anthropoids, it is longer than in the Carnivora, and passes upwards and with a marked inclination backwards; its back-

ward direction being more decided in Man than in the highest Apes.

Up to this point there does not seem to be much difficulty in finding a morphological correspondence between the fissures and convolutions in the brains of these orders of Mammals, but beyond this stage many difficulties undoubtedly present themselves. In the human brain, for example, the magnitude and direction of the convolutions of the frontal lobe, the fissure of Rolando, the parieto-occipital fissure, the definite occipital lobe lying behind that fissure, the calcarine fissure, the elongated convolutions of the temporo-sphenoidal lobe, and the convolutions of the insula are all characteristic features, which are repeated though in a less pronounced form in the brains of Apes, except that in the latter the distinctness of the occipital lobe is more accentuated. In the Carnivora and Pinnipedia again the presence of three or four tiers of convolutions with their intermediate fissures surmounting the fissure of Sylvius, the existence of a crucial fissure, and also in many genera of a præcruciate fissure and ursine lozenge, are noticeable characteristics, and at first sight seem so divergent from the human arrangement as to be apparently irreconcilable with it.

In the Human cerebrum four elongated convolutions running obliquely from above downwards and forwards intervene between the fissure of Sylvius on the cranial surface and the gyrus and lobus hippocampi on the tentorial surface; viz., the superior, the middle, and inferior temporo-sphenoidal convolutions, and the occipito-temporal convolution. In the Ape's brain the differentiation of the three temporo-sphenoidal convolutions is more or less distinct in various species, but the occipito-temporal convolution is frequently not differentiated from the inferior temporo-sphenoidal gyrus.

The apparently corresponding region in the brain of the domestic Cat is short and stunted, but in the larger brain of the Tiger it is more elongated; in the Dog's brain it is a little longer than in the Cat; in *Phoca, Macrorhinus,* and *Trichechus* it is also well marked and the convolutions are tortuous. In these Carnivora and Pinnipedia three convolutions lie behind the fissure of Sylvius on the cranial aspect of the hemisphere, for they are almost vertical in direction, and the most posterior

forms the boundary of the hemisphere at the junction of its cranial and tentorial surfaces. These convolutions are the posterior limbs of the tiers of convolutions which surmount and arch above the fissure of Sylvius. In the larger Carnivora and Pinnipedia a fourth convolution, varying in its degree of differentiation, but not recognisable in the brains of the smaller Carnivora, is situated on the tentorial surface peripherally to the hippocampal convolution, and separated from it by the splenial (limbic) fissure, which fissure is usually bridged by the retrolimbic convolution. In their relations to the Sylvian fissure on the one hand, and to the gyrus and lobus hippocampi on the other, these four convolutions in the Carnivora and Pinnipedia might seem at first sight as if they approximated to the temporo-sphenoidal and occipito-temporal convolutions in Man and Apes, though in Man they are greatly elongated and approach the horizontal in their direction, in conformity with the direction of the fissure of Sylvius. Moreover, they project in front of the uncus or lobus hippocampi so as to form the tip of the temporo-sphenoidal lobe and the greater part of the boundary of the Sylvian fossa, so that the lobus hippocampi with the short postrhinal fissure is not visible at the base of the human brain, but is displaced inwards on to the tentorial aspect. But further, in the brains of the Carnivora and Pinnipedia the lobus hippocampi appears as a distinct "natiform" protuberance on the base of the brain, and itself forms the posterior boundary of the Sylvian fossa. These differences in the two types of brain might seem to be accounted for simply by the great development and the change in direction of the convolutions of the temporo-sphenoidal lobe in the brains of Man and Apes, causing in them displacement of the lobus hippocampi to the inner surface of the hemisphere and its concealment, when the hemisphere is looked at from the cranial aspect, by the greatly elongated temporo-sphenoidal convolutions.

But I am of opinion that this does not express the whole difference between these brains in this region. In the description of the brain both of the Walrus and the Seals I have indicated that the Island of Reil may find its representative in these animals in the anterior limb of the Sylvian convolution,

which is more or less concealed within the fissure of Sylvius; and in the brain of the Polar Bear I have shown that an entire arched convolution is concealed within that fissure. If I am right in this indication, then I believe that the Island of Reil, which in the brain of the Ape and still more in that of Man is entirely concealed within the Sylvian fissure, is either the homologue of the Sylvian convolution of the carnivorous brain, or that the Sylvian convolution in the Carnivora potentially represents both that convolution and a rudimentary insula. In the true Carnivora the Sylvian convolution was as a rule superficial and on the cranial aspect, though in the Otter and Badger indications of the depression of its anterior limb within the fissure were seen. In the Seals and Walrus the concealment of this convolution was still more marked, so that the brains of these animals form apparently in this particular a transition to those of Man and Apes, in which the concealment of the Island is complete. On the supposition therefore that the Island of Reil in Man and Apes is morphologically related to the Sylvian convolution of the Carnivora, the superior temporo-sphenoidal convolution in the Human and Ape's brain cannot be regarded as corresponding with the posterior limb of the Sylvian convolution, but with that of the convolution of the tier immediately above and behind the Sylvian convolution, i.e., the 3rd external convolution of Ferrier,[1] or the suprasylvian convolution of my description. The sinking of the Sylvian convolution into the fissure may perhaps to some extent be associated with a diminution in magnitude of the olfactory apparatus. When that is large the Sylvian fissure is shallow, but when the olfactory peduncle and roots diminish in size, as in the Seal and Walrus, the fissure deepens and the Sylvian convolution becomes partially concealed, until in Apes and Man, with a still greater diminution in the importance of the olfactory sense, the fissure attains its maximum depth. In this connection, however, it must be remembered that the Polar Bear, though with an arched convolution concealed within the Sylvian fissure, yet possesses large olfactory nerve roots.

This view of the homology of the convolutions in this region enables one to harmonise the results of physiological experiment

[1] *The Functions of the Brain,* 2nd ed., London, 1886.

with anatomical arrangement, and to remove a difficulty which is experienced so long as the superior temporo-sphenoidal convolution is regarded as corresponding with the posterior limb of the Sylvian convolution. Dr Ferrier, from his experiments, determined that the areas marked (14) in his figures were the auditory centres. Thus when these areas in the superior temporo-sphenoidal convolution were stimulated in Monkeys the opposite ear became pricked, the head and eyes were turned to the opposite side and the pupils became widely dilated; whilst stimulation of areas (14) in the 3rd external convolution of the brain of the Dog and Jackal also produced a pricking or retraction of the opposite ear, and stimulation of a similar area in the Cat produced both pricking of the opposite ear and turning of the head and eyes to the opposite side. Hence these areas in the Carnivorous and Ape's brain are regarded as physiologically the same; though in the Ape the convolution stimulated bounds the Sylvian fissure, whilst in the Carnivora it is separated from that fissure by an intermediate convolution. On the theory that the Sylvian convolution either becomes the Island of Reil or blends with the insula and sinks into the fissure, the 3rd external convolution would then become the boundary of the fissure and its posterior limb would be homologous with the superior temporo-sphenoidal convolution of the brain of Man and Apes, whilst the suprasylvian or 3rd curved fissure would become lost in the Sylvian fissure, and be represented by the sulcus insulæ. This theory is somewhat different from the conception of the relation of parts in this region entertained by Ferrier, who suggests that the Sylvian convolution is in the Monkey's brain represented within the lips of the Sylvian fissure, overlapping and concealing the Island of Reil.

Ferrier has also shown that electrical stimulation of the posterior limb of the Sylvian convolution gives no definite reactions, and similarly stimulation of the Island of Reil is not followed by movements except after increased irritation, when some movements of the mouth and tongue occur, which he considers may be due to conduction of the stimulus to the motor areas situated immediately anterior to the part irritated. Ordinary stimulation in both instances therefore produces no definite results, showing that neither of these convolutions

responds to the electrical stimulus, and although the experimental result is negative, it is certainly not adverse to the view that they are homologous with each other. Confirmation of this theory is also furnished by the fact that stimulation of the area marked (16) on the lower end of the anterior limb of the Sylvian convolution in Dr Ferrier's figures of the brain of the Dog and Cat is occasionally associated with movements of the lips, whilst similar movements are produced by irritation inside the fissure of Sylvius in the Monkey,[1] doubtless due therefore to irritation of the areas (9) and (10), which lie in proximity to the fissure.

To harmonise the arrangement of the convolutions of the frontal, parietal, and occipital lobes of the Human and Ape's brain with the tiers of convolutions which in the Carnivora surmount the fissure of Sylvius, is undoubtedly a task of some difficulty. Several anatomists have, however, attempted to do so. M. Broca, in his memoir already quoted, has argued with great emphasis, that in the brain of the Primates the character which dominates over all others in importance is the enormous development of the frontal lobe, from whence results the backward position and the oblique direction of the fissure of Rolando. The position which I took up many years ago[2] that the fissure of Rolando, or central fissure, should be regarded as forming the posterior limit of the frontal lobe and the plane of demarcation between it and the parietal lobe, is now generally accepted. It becomes therefore a matter of some moment to determine if possible the fissure in the carnivorous brain which corresponds to the fissure of Rolando in Man and Apes, the oblique and backward direction of which must be borne in mind.

Broca regarded the fissure of Rolando as represented in the Carnivora by the præsylvian fissure, so that he practically confined the frontal lobe in these animals to the region in front of

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[1] I am indebted to Dr Ferrier for this information, which he wrote to me in reply to a request as to the area in the Monkey's brain which corresponds to (16) in the brain of the Dog.

[2] *The Convolutions of the Human Cerebrum Topographically Considered*, Edin., 1866, p. 11. "Notes more especially on the Bridging Convolutions in the Brain of the Chimpanzee," *Proc. Roy. Soc. Edin.*, 19th Feb. 1866, vol. v. p. 578.

and below that fissure, which has been named in this Report the supraorbital area. Schwalbe[1] is apparently inclined to attach some weight to this view; but owing to the divergence in development of the Carnivora and Ungulata on the one hand, and the Primates on the other, he does not consider it possible to make a strict comparison between the convolutions and furrows of these orders of Mammals. I believe that the limitation of the frontal lobe to the area in front of the præsylvian fissure would be too great a restriction of that lobe, which on developmental and other grounds may, I think, be shown to extend further back·in the hemisphere.

At the first glance there might seem to be a strong likeness between the crucial fissure in the carnivorous brain and the fissure of Rolando. They are both directed more or less vertically and transversely downwards on the cranial surface of the hemisphere, and each is bounded in front and behind by a gyrus having a corresponding direction; in the Carnivora the gyri are the anterior and posterior limbs of the sigmoid gyrus; in Man and Apes they are the ascending frontal and parietal convolutions. These general resemblances have led more than one anatomist to regard them as homologous. But in discussing the homology of the crucial fissure it is important to attend to its relative period of appearance on the surface of the cortex, and to its relations to the splenial fissure on the mesial aspect of the hemisphere. There can, I think, be no doubt that the anterior and upper part of the splenial fissure in the brains of the Carnivora and Pinnipedia corresponds with the fissure which is known as calloso-marginal in Man and Apes. Both the splenial and the calloso-marginal fissures are separated from the corpus callosum by the callosal convolution of the limbic lobe, and each runs in this part of its course about midway between the corpus callosum and the free upper margin of the hemisphere. In the Canidæ, the Badger, Ratel, Weasel, Ferret, Elephant Seal and Walrus the splenial fissure was continuous with the crucial fissure, but in the Cat, Tiger, Coati and Polar Bear they were not continuous; whilst in a *Phoca vitulina* the two fissures were continuous in the one hemisphere, but not in the other. In those cases in which the

[1] *Lehrbuch der Neurologie*, Erlangen, 1881.

fissures were not continuous, the splenial ended in or near the margin of the mesial longitudinal fissure in proximity to the crucial fissure and usually a little behind it.

In the human brain the calloso-marginal fissure turns round the genu of the corpus callosum and then runs backwards about midway between the corpus callosum and the margin of the great longitudinal fissure ; when a little in front of the splenium of the corpus callosum it bends upwards to reach the margin of the hemisphere somewhat behind the fissure of Rolando. Where it makes this bend a fissure is prolonged for a variable distance backwards from it, but does not reach the collateral fissure, for it is so interrupted by convolutions in this region which are continuous with the præcuneus or quadrilateral lobule, that the callosal convolution loses immediately above the splenium its sharp line of demarcation superiorly. Both in the Human brain and that of the Ape the limbic lobe, where the callosal and hippocampal convolutions approach each other, possesses a less definite differentiation peripherally than is the case both in the Carnivora and in Mammals generally, a condition which is apparently due to the much greater development of bridging convolutions at its splenial end. In the Walrus, for example, the bridging convolution in this region is a single narrow gyrus, whilst in the Human and Ape's brain they correspond to the broad base of the præcuneus. Not unfrequently I have seen one or more short fissures arise from the calloso-marginal about opposite the genu and indent transversely the superior frontal convolution at the anterior end of the cerebrum, which was bent around each fissure like a short sigmoid gyrus. In its direction and relation to the calloso-marginal fissure any one of these fissures resembled the crucial fissure, but cannot be morphologically the same as the fissure of Rolando, which is situated much farther back on the side of the hemisphere, and which has no definite relation with the calloso-marginal fissure. It is obvious that the crucial fissure is not of primary importance, as it is not always present in gyrencephalous Mammals, and in those Carnivora, such as the Dog and Cat, in which its development has been examined, it has been shown by Pansch to appear subsequently to the splenial fissure having assumed a certain depth, so that it has only a secondary value.

We must therefore look elsewhere in the carnivorous brain for the homologue of the fissure of Rolando.

Owen, from a comparative survey of the brain in a large number of gyrencephalous Mammals, was led to regard the coronal fissure in the Carnivora as corresponding with the fissure of Rolando in Man, which he also called the coronal fissure. Pansch[1] and Meynert[2] took a similar view of the homology of the coronal fissure, and Pansch held that the fissure of Rolando was the anterior part of the upper or first curved fissure, and was the second in order of position from before backwards of the three primary fissures which occur on the cranial surface of the hemisphere of all Mammals with convoluted brains. In the Primates they were placed radially above the Sylvian fissure, but in other Mammals the first or most anterior was more vertical, whilst the second and third had a sagittal direction. Pansch's determination of the homology was based on the relative period of appearance and on the depth of the fissure in various Mammals, and guided by these considerations he regarded the ascending frontal and parietal (or the central) convolutions as having their morphological equivalents in the anterior parts of the 4th and 3rd convolutions of Leuret, i.e., the sagittal and mediolateral convolutions of the Dog or the 1st and 2nd convolutions of Ferrier.

Ferrier, who was at one time disposed to agree with the anatomists who looked upon the fissure of Rolando as the homologue of the crucial fissure, now holds with those who consider it to be represented by the coronal fissure, and he supports his present opinion by the result of his experiments on the cerebral cortex in Monkeys and Carnivora. From a comparison of these results it would seem that a number of the effects produced are reconcilable with the view that parts of the brain in front of the fissure of Rolando and of the coronal fissure in these animals are physiologically homologous. Thus the area marked (12) by Ferrier, which in the Monkey includes the posterior half or two-thirds of the superior and middle frontal convolutions, and in the Dog is situated on the anterior limb of the sigmoid gyrus, when stimulated occasioned in both animals

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[1] *Centralblatt f. d. med. Wissensch.*, 1875, No. 88.

[2] *Archiv f. Psychiatrie*, Bd. vii., 1877.

wide opening of the eyes, dilatation of the pupils, and turning of the head and eyes to opposite sides; stimulation of the area (3), which in the Monkey lies in the upper end of the ascending frontal convolution close to its sulcus, and in the Dog in the 1st external or sagittal convolution just behind the crucial sulcus produced in both animals movements of the tail; stimulation of the area (4), situated in the Monkey in the upper end of the ascending frontal and anterior margin of the adjacent part of the ascending parietal convolution, and in the Dog in the back of the posterior limb of the sigmoid gyrus, produced corresponding movements in the fore limbs of both animals; stimulation of (5), situated in the Monkey in front of (3) where the superior frontal joins the ascending frontal, and in the Dog in the sigmoid gyrus about opposite the outer end of the crucial fissure, occasioned in both animals an extension forward of the opposite fore limb. It will also be observed that the area marked (12) in both animals was the most anterior region to respond to electrical stimulus. These experiments all indicate a homology between both limbs of the sigmoid gyrus in the Dog and the ascending, superior, and middle frontal convolutions in the Monkey, which is incompatible with the view that the crucial fissure is the homologue of the fissure of Rolando, but quite reconcilable with the theory that the coronal fissure and fissure of Rolando are homologous; for in the respective brains both the coronal and Rolando's fissures lie behind the areas stimulated, with the exception of a small part of (4), which just touches the ascending parietal convolution.

On the other hand, it is more difficult to reconcile some other of Ferrier's experiments with this conclusion as to the homology of the two fissures. For stimulation of area (1), placed in the Monkey in the postero-parietal convolution just in front of the parieto-occipital fissure, and in the Dog in the posterior limb of the sigmoid gyrus just behind the crucial fissure, produced in both animals an advancement of the opposite hind limb as in walking; in the Monkey the area stimulated was distinctly behind the fissure of Rolando, in the Dog well in front of the coronal fissure. Again, the areas (7) (8), which, when stimulated, gave rise to movements of the zygomatic muscles and upper lip, lie in the Monkey in the ascending

frontal convolution, and therefore anterior to the fissure of Rolando; but in the Dog the one is situated in the coronal part of the 2nd external convolution, the other in the anterior composite convolution formed by the junction of the anterior ends of the 2nd and 3rd external convolutions, and both therefore are behind the coronal fissure.

If we regard, however, the whole evidence based on comparative anatomy, on the depth and relative time of appearance of the fissures, and on the results obtained by stimulating the brain in front of the fissures, we may, I think, fairly assume the fissure of Rolando to be homologous with the coronal fissure in the carnivorous brain. The sigmoid gyrus, with the adjoining part of the sagital convolution, and in animals which have an ursine lozenge that area also, would therefore represent the superior, middle, and ascending frontal convolutions in the brain of Man and Apes.

But there are other fissures in the brains of these Mammals the homologies of which it is desirable, if possible, to determine. A well-marked fissure in the carnivorous brain is the præsylvian or supraorbital fissure. It is the most anterior of the three primary fissures described by Pansch as appearing on the cranial surface of the brain of the fœtal Dog, and it separates in this animal the anterior limbs of the four tiers of convolutions from the supraorbital area and the prorean convolution. If we place side by side the hemispheres of the Human and the Dog's brain, we can see in the former two fissures, the præcentral fissure of Ecker and the ascending branch of the Sylvian fissure, one or other of which would appear to represent the præsylvian fissure in the Dog. Meynert was of opinion that the præsylvian fissure is homologous with the ascending branch of the Sylvian fissure. Broca objected to this[1] on the ground that the ascending branch, whilst present in Man and the Anthropoid Apes, is absent in the non-anthropoid Apes; and that it is not likely that a character which is only found in the most highly developed brains of the Primates should, when absent in the lower Apes, reappear in the Carnivora in which the frontal lobe is only rudimentary. In connection with this matter it should be stated that the area (8), which Ferrier

[1] "Sur le Cerveau du Gorrille," *Revue d'Anthropologie,* sér. 2, t. i.

associates with elevation of the upper lip, so as to display the canine teeth, is situated in the Monkey in the lower part of the ascending frontal convolution, and in the Dog at the anterior composite end of the 2nd and 3rd external convolutions; whilst the area (9), which he associates with the opening of the mouth, movements of the tongue, and not unfrequently barking or growling, is situated in the Monkey in the lowest part of the ascending frontal convolution, where the inferior frontal convolution springs from it; and in the Dog in the composite convolution formed by the junction of the lower ends of the anterior limbs of the 3rd and 4th external convolutions. Areas (8) and (9) are placed, therefore, in the Monkey immediately behind the præcentral fissure, and in the Dog immediately behind the præsylvian fissure.

The results obtained by experiment would seem therefore to harmonise with the conclusion founded upon more purely anatomical data, and I think it probable that the præsylvian and præcentral fissures are homologous.

A number of years ago I described in the brain both of the Chimpanzee and of Man [1] a fissure within the parietal lobe, which I named the intraparietal fissure.[2] It is situated in the first instance behind and parallel to the ascending parietal convolution, and then runs almost horizontally backwards to separate the ascending and postero-parietal convolutions from the supramarginal gyrus or convolution of the parietal eminence, and it may be seen in the brain of a six months' human fœtus. Pansch subsequently recognised the importance of this fissure, and regarded it as the third and most posterior of the three primary fissures on the cranial surface of the brain; he believed it to be homologous with the anterior part of the middle or second curved fissure of the Dog—the lateral fissure of this memoir.

In the human brain the intraparietal fissure is separated from the Sylvian fissure by a convolution which, under the name of supramarginal gyrus, or, as I have termed it, the convolution of the parietal eminence,[3] forms a single tortuous tier.   In the

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[1] See my Memoirs already quoted, pp. 95, 126.
[2] Ecker and some other anatomists have misnamed it the interparietal fissure.
[3] " Relations of the Convolutions of the Human Cerebrum to the Outer Surface of the Skull and Head," *Jour. of Anat. and Phys.*, vol. viii. p. 142.

Dog, again, two tiers lie between the lateral and Sylvian fissures, viz., the suprasylvian and Sylvian convolutions, separated from each other by the suprasylvian fissure. Pansch makes no attempt to explain this difference, and, in the absence of such explanation, difficulties at once suggest themselves as to accepting his view of the homology of the intraparietal fissure and the anterior part of the 2nd curved fissure. But, on the theory which I have expounded on p. 567, that the Sylvian convolution of the Dog subsides in Man and Apes into the Sylvian fissure, and that the suprasylvian and Sylvian fissures become, as it were, thrown into one, then one can account for the presence of only a single convolution on the lower aspect of the intraparietal fissure, which convolution represents the anterior limb of the suprasylvian convolution of the Dog, and is the supramarginal convolution in the higher brains. Ferrier's experiments also to some extent bear out this view; for his area (11), stimulation of which produces retraction of the angle of the mouth, is situated in the Monkey partly in the lower end of the ascending parietal, but more so on the adjoining supramarginal gyrus, and in the Dog in the anterior limb of the suprasylvian convolution.

One of the most noticeable fissures of the cerebrum of Man and Apes is that which, under the name of parieto-occipital fissure, separates the parietal from the occipital lobe. In the human brain it is as a rule more strongly marked on the mesial than on the cranial aspect, owing to the development on the cranial surface of strong bridging convolutions which pass across its upper end. In the brains of Apes it is as well marked on the one surface as on the other, though in the brain of both the Orang and Chimpanzee superficial bridging convolutions sometimes obscure its upper end.[1]

Almost all writers have stated that this fissure is absent in the brains of the Carnivora, so that in them the occipital lobe is not differentiated from the parietal part of the brain. In a recent memoir,[2] however, Max Flesch has described in the brain of the Brown Bear (*Ursus arctos*) a short fissure as arising from

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[1] See my "Notes more especially on the Bridging Convolutions in the Brain of the Chimpanzee," *Proc. Roy. Soc. Edin.*, vol. v. p. 578.

[2] "Versuch zur Ermittelung der Homologie den fissura Parieto-occipitalis bei der Carnivoren," *Festschrift für Albert Kölliker*, Leipzig, 1887.

the highest part of the fissure which he calls middle-curved or suprasylvian, but which I have named in this Report 2nd curved or lateral fissure, and as passing towards the mesial longitudinal fissure, near its hinder end, though without reaching it. He represents it arising by a stem about 3 mm. long, and then as bifurcating into an anterior and a posterior part, of which the latter is apparently the deeper. On the mesial surface of the hemisphere, however, there is no fissure which could be regarded as parieto-occipital. He considers that in the brain of this Bear the upper curved fissure is only partially present, as in the short coronal fissure and one or two other short fissures near it. He associates the appearance of a parieto-occipital fissure as in direct relation to the disappearance of the 1st curved fissure, also to the metamorphosis of a part of this fissure into the fissure of Rolando (central fissure) and to the disappearance (Rück-bildung) of the crucial fissure. He obviously considers that in the corresponding part of the brain of the Felines there is an indication of a parieto-occipital fissure, but that this fissure is absent in all carnivorous brains where the three curved fissures are completely developed.

I have examined the brain of *Ursus maritimus* with the object of seeing if a corresponding fissure existed in it. In the right hemisphere a shallow fissure situated at a corresponding spot did for about 4 mm. indent the marginal convolution in the same region as in *Ursus arctos*, and a somewhat longer one was present in the left hemisphere. These fissures were so short and shallow that they gave me the impression of being quite subordinate furrows. On the other hand, the parieto-occipital fissure in the brain of Man and Apes is one of primary import-ance; it appears in the human foetus at about the fifth month, and is especially marked on the inner side of the hemisphere; whilst neither in *Ursus arctos* nor *Ursus maritimus* was there any evidence of a fissure which corresponded with the internal parieto-occipital fissure of the human brain.

Dr Murie, in the course of his description of the brain of *Otaria jubata*, employs to a large extent the terminology of human anatomy, and believes that he can recognise in the brain of this Eared Seal the majority of the convolutions and fissures present in the human brain. Amongst other fissures he de-

scribes, by the name of internal perpendicular, the fissure which is more usually named parieto-occipital. He figures it as indenting the marginal convolution towards the hinder end of the hemisphere, and as present both on the mesial and cranial surfaces. In conformity with the method of nomenclature which he has adopted, he has named the convolution in front of the inner part of this fissure the quadrilateral lobule of the parietal lobe, whilst that which lies behind it he names the internal occipital lobule. In the brains both of the Elephant Seal and Walrus the marginal convolution was indented, in a position almost corresponding to that in *Otaria jubata*, by a continuous fissure both on the cranial and mesial surfaces, the length of which was, however, variable in the different brains, especially on the mesial surface. Partly owing to this variability, and partly because we have no information on the development of this fissure in the Pinnipedia, I am not prepared to say that it is homologous with the parieto-occipital fissure of the human brain.

The evidence obtained from experiments on the cerebral cortex has established the important fact that stimulation of the occipital lobe in the brain of the Monkey produces no definite reaction; whilst stimulation of the angular gyrus, both in its anterior and posterior limbs (13), affects the pupils and occasions movements of the eyes to the opposite side, so that this convolution is a visual centre.[1] In the Dog also the most posterior parts of the 1st and 2nd external convolutions do not respond to stimulus, whilst a portion of the 2nd external convolution in front of the most posterior part (13), when stimulated, gives reactions similar to those obtained from the angular gyrus in the Monkey. There is reason to think, therefore, that the most posterior parts of the 1st and 2nd external convolutions of the Dog are potentially equivalent to the occipital lobe in the brain of the Monkey, although they are not differentiated by a parieto-occipital fissure, whilst the 2nd external convolution immediately in front of the part which does not respond to stimulus and the angular gyrus are homologous with each other physiologically. In all probability these convolutions are also anatomically identical, for Gratiolet, who was the first to differ-

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[1] See the researches of Ferrier and other experimentalists.

entiate the angular gyrus (*pli courbe*) in the brain of Man and Apes,[1] places it behind the supramarginal gyrus, *i.e.*, behind the tier of convolutions immediately above the Sylvian fissure, and therefore in a position corresponding to what that part of the 2nd external convolution which gives a similar response to stimulus would assume were this convolution in the Dog's brain pushed backwards by a great development of the frontal lobe.

The general results arrived at in this comparison of the brains of these Mammals are to some extent to be regarded as tentative and provisional. For, until the development of the fissures and the development and structure of the convolutions have been worked out with greater detail than up to this time has been done, it will not be possible to speak with certainty on all the points which have to be considered in a detailed comparison of the cortex of the cerebrum in the Carnivora with that of Man and Apes. Further, it should be stated that in this, as in other organs of complex constitution, it does not follow that all the parts which are seen in the more highly developed brains are of necessity present, even in a rudimentary condition, in those whose organisation is not so complicated. It must also be remembered that whilst the brains of the Carnivora, and still more so those of the Pinnipedia, are highly convoluted, those of such Apes as the Marmoset Monkey (*Hapale jacchus*) are smooth on the surface, and, with the exception of the large surfaces separated by such fissures as the Sylvian and hippocampal, have no definite subdivision into morphological areas which are capable of being recognised by the naked eye. But both in the Marmoset Monkey and in such other New World Apes as *Œdipus*,[2] in which the convolutions are either absent or rudimentary, the cerebral hemispheres are prolonged forwards to the front of the olfactory bulbs and backwards above the cerebellum to an extent which is not seen in the Carnivora. In this respect, therefore, these brains, though either without convolutions or having them only feebly developed, are more highly organised than is the case in the Carnivora proper or in the Seals.

[1] *Mémoire sur les plis cérébraux de l'homme et des primates*, Paris, 1869.
[2] See Gratiolet, *op. cit.*

From the point of view of the hypothesis of evolution there would be no reason to think that the smooth-brained lower Apes had originated out of the Carnivora, at least after the cortex of the cerebrum in this latter order had begun to assume a convoluted arrangement. If they had been derived from a carnivorous animal with a convoluted brain, then in all likelihood the convoluted character of the cerebrum would not have disappeared in the process of evolution. If the higher Apes have been derived by descent from the lower Apes, then the hemispheres in the former, with their. complex arrangement of

TABLE.

Dog.	Monkey.
Fissures.	*Fissures.*
Sylvian, ...	Sylvian.
Hippocampal, . . .	Hippocampal.
Splenial, ...	Collateral and calloso-marginal.
Olfactory, ...	Olfactory.
Intraorbital, ...	· Triradiate.
Coronal, ...	Rolando's.
Præsylvian, ...	Præcentral.
Anterior part of lateral, . .	Intraparietal.
Convolutions.	*Convolutions.*
Callosal, ...	Callosal.
Hippocampal, . . .	Hippocampal.
Lobus hippocampi, . .	Uncinate or uncus.
Gyrus rectus, . . .	Gyrus rectus.
Internal supraorbital, . .	Internal supraorbital.
External supraorbital, . .	External supraorbital.
Sylvian, ...	Island of Reil in whole or in part.
Posterior limb of suprasylvian,	Superior temporo-sphenoidal.
Sigmoid gyrus, part of sagittal convolution and composite convolutions,	Ascending, superior, middle and inferior frontal convolutions.
Anterior limb of suprasylvian,	Supramarginal or convolution of parietal eminence.
Part of 2nd external convolution posteriorly,	Angular gyrus.
Most posterior part of 1st and 2nd external convolutions,	Occipital lobe.

fissures and convolutions, have been evolved from a smooth-brained stock and not from an animal with such an elaborate arrangement of convolutions as is possessed by either a Dog or a Seal. Hence the acceptance of this hypothesis is not inconsistent with the fact that the convolutions of the brain in the Apes assume from the first their own method of arrangement, and not necessarily that of the orders of Mammals with convoluted brains which are lower in the series. Beyond therefore a certain general correspondence in the arrangement of those fundamental parts of the cortex which serve a similar purpose in these various orders, one does not find it possible to determine the presence of convolutions arranged in a precisely corresponding manner in the brains of the Carnivora and Pinnipedia on the one hand, and of Man and Apes on the other. In each of these orders the developmental process which gives rise to the disposition of the fissures and convolutions is regulated by the vital and mechanical necessities of the animals constituting the order, as well as by the conditions of hereditary descent. Subject to the qualifications and reservations which have been just expressed, and with the *proviso* that the homologies of the cortical areas of the cerebrum are in many instances histological and physiological rather than morphological, the summary of the corresponding fissures and convolutions in the Dog and the Monkey has been drawn up in a tabular form on p. 580.

On both the numerical and descriptive methods the following are the synonymous terms employed in this account of the carnivorous brains which possess four tiers of convolutions:—

1st external convolution,	Sagittal or marginal convolution.
1st curved fissure,	Mediolateral or sagittal fissure.
2nd external convolution,	Mediolateral convolution.
2nd curved fissure,	Lateral fissure.
3rd external convolution,	Suprasylvian convolution.
3rd curved fissure,	Suprasylvian fissure.
4th external convolution,	Sylvian convolution.

MORPHOLOGICAL CHANGES THAT OCCUR IN THE HUMAN BLOOD DURING COAGULATION. By Professor JOHN BERRY HAYCRAFT and E. W. CARLIER, M.B., *Physiological Laboratory, University of Edinburgh.*

[Towards the expenses of a research, a part of which appears in this communication, a grant was made by the British Medical Association, on the recommendation of the Scientific Grants Committee of the Association.]

DR FREUND and Professor Haycraft,[1] working independently, have succeeded in keeping blood in a fluid state when removed from the circulation.

Dr Freund found that if he smeared a glass vessel with vaseline, and carefully received blood into it through a greased cannula in direct communication with the artery of an animal, he could, by covering the blood so obtained with a layer of liquid paraffin, keep it from coagulating for several hours.

Professor Haycraft found that by allowing blood to drop through a layer of liquid paraffin on to greased mica plates, he could keep the drops liquid for some time. Care had to be taken in these experiments to prevent the blood from coming into contact with a foreign body, such as a knife. This was done by everting the cut end of the vein from which the blood was to be taken over a short glass tube, the blood escaping directly into the paraffin without touching the cut edge of the vein.

Professor Haycraft also succeeded in keeping the blood fluid by pouring into a venous capsule, containing some blood, a large quantity of a mixture of vaseline and paraffin, and shaking this mixture from time to time with the blood. In this way blood-globules were isolated by the paraffin from contact with the vascular wall. They remained fluid for some hours.

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[1] "An Account of some Experiments which show that Fibrin Ferment is Absent from Circulating Blood-Plasma," *Proc. Roy. Soc. Edin.*, July 1887, and *Journ. Anat. and Phys.*, vol. xxii.

In principle all of these methods are the same. In each case the blood is surrounded by *fluid* of a surface-tension different from its own, and which does not mix with it.

These experiments support a theory that Sir Joseph Lister advanced with so much argument and experimental evidence, viz., that blood does *not tend* to coagulate within the body, and that when it clots in a cup or in contact with any solid matter, the clotting is brought about by the action of the solid itself on the blood.

Of course if the blood can be removed from the body and kept in a fluid state in oil, there is no reason to agree with Sir Astley Cooper that, within the body, the vitality of the vessels prevents its coagulation.

These experiments bring one to the threshold of a most interesting inquiry as to what can be the action of a chemically inert solid—it may be a piece of metal, glass, or porcelain—when it produces, by mere contact, such important changes in the blood.

The writers of this communication have set themselves to answer this question.

The methods already described for keeping blood fluid outside the body could not, for obvious reasons, be applied to the human subject, and it was our wish to obtain some method by means of which we could experiment with our own blood, and one which might be available clinically.

After some experimentation we elaborated the following method, which exceeded the anticipations we had formed of it.

This method consists in receiving a drop of blood from a carefully greased finger into a very viscous fluid. The drop will sink slowly, owing to the viscosity of the fluid, and by reversing the vessel backwards and forwards it may be kept in the fluid and away from the sides of the vessel for a considerable time.

The apparatus consists of a straight cylindrical vessel, $1\frac{1}{2}$ inch in diameter and about 1 foot in length, closed at one end and open at the other. The edge of the open end is ground perfectly level, so that a plate of glass may be adapted accurately to it.

This apparatus having been placed with its closed end down-

wards, is carefully filled with castor oil, a very viscous fluid, care being taken to prevent bubbles of air from being carried down into the tube with the oil. When the tube is completely filled with oil, blood is introduced into it in the following way:—The finger, having been rendered turgid by a bandage, is well smeared with some of the oil and plunged into the vessel; a needle is introduced, and the finger pricked just above the nail beneath the surface of the oil.

In this way several drops of blood may be obtained from the same puncture, and as the blood flows into the oil, the size of the drops can be regulated to a nicety.

From this it will be seen that the blood so obtained comes into contact only with the tissues of the finger in the puncture, neither the surface of the skin, nor the air, nor any particle of dust being permitted to contaminate it. By gently shaking the finger, the drops may be detached from it; the finger is then withdrawn, and the drops begin to descend in the oil. The tube should next be filled to the brim with oil and the glass plate slipped on, care being taken not to include any bubbles of air, as these tend, when the tube is inverted, to rise, and by touching the blood, spoil the experiment.

It is well to obtain several drops of blood of various sizes in the tube at the same time; they will be seen to gradually separate the one from the other as they descend, the largest falling with the greatest rapidity. It takes an average-sized drop ten to fifteen minutes to fall one foot in *such an oil.* When the largest drop has nearly reached the bottom (it must on no account be allowed to touch the glass, or the experiment will fail), the tube should now be inverted, and the drops will again begin to fall. It will be seen that the larger drops which have fallen in front of the smaller ones will reach them again when they arrive at the bottom of the vessel which is now inverted. The vessel may be inverted again and again as required.

The movable glass plate is now drawn off gently; part of the oil with the drops of blood is allowed to flow into a porcelain capsule or other shallow vessel. The drops can be taken out of the porcelain vessel with a well-oiled spoon, and placed upon a glass slide. Now, as the oil and blood have no tendency to mix,

the drop can, by tilting the slide, be caused to run off on to another clean glass slide, and there examined. It will be found, on drawing a needle through the drop, that it is perfectly fluid, there being an entire absence of any coagulation, even in the form of the minutest traces of fibrin threads.

That the blood does not coagulate can indeed be seen in another way. If the drops be watched as they fall they will be seen soon to differentiate into two parts; the corpuscles will sink to the bottom of the drop, and the clear plasma will form a layer of a faint yellowish tint at the top.

We believe that this is the first method by which human blood-plasma, unaltered physically and chemically, has ever been demonstrated except in microscopic quantity. We have kept blood fluid in castor oil for nearly an hour, and with almost invariable success. We have had no occasion to preserve it fluid for a longer period. It is probable that, owing to the blood coming in contact with the tissues in the wound, an infinitesimal amount of ferment is set free, which will eventually cause clotting, even though the blood is surrounded by oil.

Action of Solid Matter on White Blood Corpuscles.

There are at least two sorts of white blood corpuscles in circulating blood—finely and coarsely granular—as can be seen at any time by examining the mesentery of an animal under the microscope. Now both these kinds of corpuscles when within the circulation are rounded in shape, exhibiting no amœboid movement, except in those cases in which diapedesis occurs.

In the blood from our own bodies which we examined, and which was in all respects normal, both of these varieties of white corpuscles occur.

If human blood be received on a slide at a temperature below 65° F. (=18°·3 C.), the white corpuscles remain rounded. If, however, the temperature be elevated to about 68° F. (=20° C.) they soon exhibit movement. If the temperature be raised to 74° F. (=23°·3 C.) they become almost immediately very actively amœboid.

Experiment I.—Temperature of room and oil, 70° F. (= 21°·1 C.) Time, 2.51 P.M.

A drop of blood was received from a well-greased finger, rendered turgid by a bandage, into a tall cylindrical vessel full of pure castor oil (see description of method).

The blood under these conditions was invariably found to have retained its fluidity after from half an hour to an hour's immersion in the oil. The finger, having been withdrawn from the tube, was wiped, and a drop of blood from the same puncture placed upon a carefully-cleaned and dust-free glass slide, where it was covered, and the cover ringed with oil to keep the blood from further contact with air and dust. This specimen was used as a test specimen.

At 2.55 P.M. the blood on the slide was examined under the microscope. Amœboid movements could be distinctly seen in the white corpuscles, which became gradually more active till, at 2.58 P.M., fibrin threads were observed to be forming. At 3.3 P.M. the white corpuscles were still actively amœboid, though the field of the microscope was thickly covered with delicate fibrin threads.

The blood was removed from the tube after twenty minutes' immersion in the oil, by allowing the drops, with some of the oil, to flow out of the tube into a porcelain capsule; they were then transferred with a well-greased spoon on to a glass slide, previously rendered quite clean. By tilting the slide the drop of blood was freed from the oil, and was then covered and examined.

The white corpuscles were all globular, but after three or four minutes they began to become irregular in shape; the red corpuscles were crenated in almost every case, though not universally so. The white corpuscles continued to exhibit amœboid movements as long as examined (some thirty minutes), though thick fibrin threads had by this time been formed.

Some of the white corpuscles, however, did not exhibit any amœboid movements, even at the end of thirty minutes, but appeared to be abnormally transparent.

This experiment appeared to us to be highly satisfactory, showing as it did that the blood, so long as protected by immersion in the oil, had not changed, whilst that not so protected had shown changes long before, as regards both formation of fibrin and amœboid movements of corpuscles. It will be observed that when the blood was withdrawn from the protecting medium and brought into contact with glass, an inert solid, it quickly began to show all the phenomena of coagulation.

This experiment is sufficient in itself to prove that the condition which varied in the two cases, namely, contact with an inert solid, was the determining cause of the production both of fibrin and the amœboid movements observed. On other occasions we repeated this experiment corroborating, as will

be seen, the truth of our previous results in all essential particulars.

Experiment II.—Temperature of the room and oil, 72° F. (= 22°·2 C.). The apparatus and method employed being similar to that described above.

Blood was examined after having remained thirty minutes in the oil. The red cells quickly became crenated, and the elementary granules ran together into masses. The white blood corpuscles, at first spherical, quickly became amoeboid and transparent, remaining so long after coagulation had occurred.

These results have been obtained after much experimenting and several failures, as the temperature was often varied, and led us to the conclusion that at a temperature below 65° F. (= 18°·3 C.) the blood was so cooled as to prevent the white cells from exhibiting their amoeboid movements under any condition, although the blood would clot at that temperature, the solid matter still causing metabolic changes, though not visible motion in the corpuscles.

We found also that at a temperature above 74° F. (= 23°·3 C.) the corpuscles became so quickly amoeboid as to prevent definite observations from being made.

We believe that these experiments demonstrate conclusively that glass and other chemically inert solids act as stimuli to the white corpuscles, as indicated by the fact that they exhibit amoeboid movement if the temperature permits. The stimulus is of the nature of a purely *mechanical stimulus.*

As a result of its action metabolic changes occur in the cells, associated at certain temperatures with changes of form.

This result is in accordance with what we know of the nature of protoplasm generally, namely, that it is irritable in an eminent degree whether the stimulus be chemical, *mechanical*, thermal, or otherwise.

The white corpuscle, devoid of an envelope, is exposed to the full stimulating effect of mechanical irritation. When the corpuscle is examined at a temperature below 65° F., the cell no doubt is stimulated, though probably to a slighter extent, owing to the cold, and we observe no movement. This is in accordance with generally observed facts concerning the action of heat and cold on animal tissues.

A fact also worthy of notice (and previously observed) is that the white corpuscles tend to stick to glass or other solid matter. The observations of Sir Joseph Lister on the adhesive character

of leucocytes in inflammatory condition, may probably be explained on the assumption that the altered tissue acts like solid matter.

Do White Blood Corpuscles break down during Coagulation?

The generally accepted theory as propounded by Schmidt[1] and others, is that coagulation is the direct result of death of the blood, especially that of the white corpuscles, which in dying produce a ferment which, acting on certain constituents of the blood-plasma, produces fibrin.

Schmidt maintains that there are two kinds of corpuscles, one kind breaking down during coagulation, the other persisting.

"As soon as the blood is shed from an artery, enormous numbers of colourless corpuscles are dissolved (Montegazza) ; according to Alex. Schmidt, 71·7 per cent. in the blood of the horse. The products of their dissolution are dissolved in the plasma."

We are certain of the following facts, namely, that some at least of both the fine and coarse varieties of white blood corpuscles are always found alive after coagulation, which occurs in our own blood never later than five to ten minutes after the blood has been shed. We have some drawings of moving cells in blood which had clotted two days previously.

In addition to this, however, we believe that *very few, if any*, corpuscles break down during coagulation, as is generally held to be the case.

If we examine a drop of blood, and note the position of several white blood corpuscles in a field, and then examine this same field after a lapse of some time, we may see some of the corpuscles showing changes other than mere amœboid motion. They are apparently breaking down. These cells, however, stain readily with dyes, and have their nuclei distinctly visible, and, moreover, these peculiar changes do not occur in less than a quarter of an hour, in fact after coagulation has taken place.

In proof that cells rapidly break down when blood is shed, it is urged that the number of white corpuscles in defibrinated blood is less than in circulating blood. But conclusions drawn

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[1] A. Schmidt, " Uber den Faserstoff und die Ursachensen seiner Gerinnung," *Müller's Archiv*, 1861, pp. 545–587 and 6757–21.

from such a comparison are obviously fallacious. It will be seen at once that the very fact of whipping the blood produces a clot on the whip which entangles a large number of white corpuscles, which will thus be abstracted from the blood. We have experienced ourselves, too, the difficulty there is in comparing the number of corpuscles in one specimen with those in another, especially when we have been labouring under any preconceived idea, and we place more reliance on the more direct method we have employed.

We used in all cases the following method, which enabled us to examine blood in microscopic quantities; its coagulation being postponed for at any rate a few minutes, any immediate breaking down of corpuscles could not have escaped our observation.

A slide is well cleaned, so as to remove all foreign matter, and a small piece of pure, dust-free vaseline is placed upon it, and protected from dust. A cover-glass is next cleaned in the same careful manner, and brought down upon the vaseline and pressure applied, to obtain a flat, airless layer of vaseline between the two. The thumb is then rendered turgid by winding a handkerchief round its base, tightly enough to prevent the venous return, but not tightly enough to prevent the arterial flow. The thumb is next smeared with vaseline, and a drop of blood obtained by pricking it with a greased needle, through the protecting layer of vaseline. The cover is then removed from the slide by sliding it to the edge and pulling it off; in this way a smooth layer of vaseline is left both on the slide and on the cover. The blood, as soon as obtained, was transferred to the slide so prepared, and covered.

Great care had necessarily to be taken to prevent particles of dust from falling on the vaseline during the few moments the cover is removed, and this was effected by holding the vaseline-covered surface downwards.

Many observations were made with this method and drawings of corpuscles taken. In all some fifty specimens were examined, and the corpuscles in each of them drawn and counted every four or five minutes, sometimes for thirty or forty minutes, giving us a series of drawings in which the following might be observed. The corpuscles of the coarsely granular

description could be seen to become at first flattened and irregular in outline, due to amœboid movement. They then lost their granules, or these retired to one part of the cell, the remainder of the cell becoming clear. This generally occurred within the first five minutes. Then strings of fibrin could be seen gradually forming. After a time the cells become very much spread out and less visible, but as long as observed they had not disappeared. This was long after coagulation had occurred.

The finely granular corpuscles were observed to present the same appearance, with the exception that their fine granules did not congregate to the same extent.

In no case, therefore, were white blood corpuscles seen to break down within fifteen minutes, thus proving that the idea that some corpuscles break down at once on the shedding of the blood is not tenable.

It will also be observed that, in our experiments with castor oil, detailed above, no white corpuscles were ever observed to break down, though in all cases some became abnormally transparent after contact with the slide; this occurred, however, long after coagulation.

From these experiments we draw the following general conclusions as regards blood shed from the body. If the weather be warm, amœboid movement of white corpuscles begins after from one to ten minutes, depending on the temperature. The movement in some cases lasts for hours. In other cases the cells change in from a quarter of an hour to two or three hours, becoming pale, indistinct granular masses, with their nuclei still visible and still capable of being easily stained. If the weather be cold, no amœboid movement is discernible, but the other changes go on as above.

Whether or not any of the cells after coagulation break down, we do not discuss. When removed from the body of course they ultimately die.

Conclusion.—Solid matter mechanically stimulates the white corpuscles of the blood, leading to amœboid movements if the blood be not cooled. In any case, some metabolic change, associated with formation of fibrin, occurs in the white corpuscles, whereby they are led to contribute to the production

of fibrin. The stimulus in the case of exceptional cells may be so strong or so continued as eventually to lead to an apparent or real breaking down, which occurs, however, only after, and sometimes long after, coagulation is complete.

Inert Solids, and their Action on Blood-Plates.

This subject was suggested by Professor Greenfield, and the work was done by his kind permission in his wards at the Royal Infirmary. We had also the advantage of the assistance of his demonstrator, Dr Gibson, who has large experience in working with blood-plates.

In all these experiments the blood of patients suffering from chronic diseases was examined, as in these cases blood-plates are more numerous than in healthy individuals. The method used was in all cases the one mentioned at the commencement of this communication.

Experiment I.—Jannette MacK., aged 18, suffering from chronic phthisis.

Blood was received directly from the patient's finger into castor oil, and kept in it for half an hour. When removed from the oil it was received on to a slide, perfectly cleaned, and having upon it a drop of osmic acid. Now, it is well known that osmic acid has the remarkable property of fixing the blood immediately on coming in contact with it. Therefore the blood from the oil, when received into the osmic acid, would be fixed in the state in which it happened to be at the time.

The blood so treated was covered with a thin cover-glass, and examined with a $\frac{1}{12}$th inch water-immersion lens.

When a drop of blood is mounted on a slide and examined, the blood-plates, which are round or oval in shape and float about singly in circulating blood, run together and form granular masses. The plates become sticky, adhering not only to one another, but any solid particles in the field. They seem to change their shape, exhibiting irregular outlines. If these changes had occurred during their sojourn in the oil, we should have found granular masses and no isolated blood-plates. The blood was, however, found to be normal in character like circulating blood; the blood-plates could be seen in the fluid with their normal histological characters. They were floating about, and presented smooth outlines.

Experiment II.—Duncan M'N., aged 19. Case of chronic phthisis.

The blood of this patient was treated in the above manner, being in the oil about thirty minutes. When examined in osmic acid it presented all the appearances of normal circulating blood.

Experiment III.—John M., aged about 30. Case of chronic phthisis.

In this case, also, the blood was treated as before, and Dr Gibson declared that had he not seen the experiment he would have believed it to be blood received from the wound directly into osmic acid.

These experiments show, therefore, that blood-plates are in no way altered by removal from the body—the formation of granular masses, their changed shapes and outline, being due to the action of solid matter.

Conclusion.—The action of an inert solid on blood-plates is much the same as its action on white blood corpuscles. It causes them to become sticky, to run together, lose contour, and change their shape.

The life-history of these blood-plates has certainly not been made out. They have been described as special and peculiar elements of the blood, but their origin and ultimate destiny has never been explained. They seem, both from their appearance and by their undergoing changes on irritation, to be pieces of undifferentiated protoplasm.

These changes which we have described are the morphological changes which occur in the blood during coagulation. These experiments do not in any way determine the part played by the white corpuscles, or so-called blood-plates, in the chemistry of coagulation, although they suggest that, as far as these bodies are concerned, coagulation is the result of living metabolism rather than of death and disintegration.

THE ANATOMY AND PHYSIOLOGY OF THE SHOE-MAKER. By W. ARBUTHNOT LANE, M.S., *Assistant Surgeon to Guy's Hospital, and to the Hospital for Sick Children, Great Ormond Street.* (PLATE XIX.)

THE body—the changes in whose anatomy forms the subject of this paper—was sent to the hospital for dissection. I was therefore enabled to observe accurately every structural variation that had resulted from the habitual performance of a definite series of movements, entailing the expenditure of a considerable amount of muscular energy during the greater part of a long lifetime of seventy-three years.

Having concluded, from a careful examination of the changes which the body presented, that the man had been a shoemaker, I wrote to the medical officer of the infirmary in which he died for any information he could give me, and he kindly informed me that the man was entered on the books as a shoemaker.

An occupation such as this is one which, when the person engaged in it is in very indigent circumstances, is carried on without variation during the whole adult lifetime of the individual, and is not, as in many kinds of labour, relinquished of necessity as old age approaches for others which are less laborious. I believe that it is by the careful observation of the changes in form and structure which bones, joints, and muscles undergo, when exposed to the influence of a series of definite movements, that we shall obtain an accurate insight into the various factors that determine not only the variations in the character of these structures in individuals of the same race, but also in members of the different races of man and of the quadrumana, together with the manner in which the factors evolved by an alteration in habits, resulting from a change in the surroundings, experience, &c., of the individual, caused alterations in the shapes of the bones, &c., and so produced new types.

I would therefore make no apology for describing most minutely the deviations from the normal type which the skele-

ton of this man presented, were it not that I feel such a description would prove very tedious to my readers. On that account I have rendered the descriptions of the anatomical conditions *as brief as possible,* though I trust not too brief to be intelligible. In considering these changes, I will proceed in a manner the reverse of that which I was obliged to pursue in examining the body, since I was at that time uncertain as to the man's occupation. The reader is probably familiar with the manner in which shoemakers perform their work, so that I need hardly describe its details. I will select the most important function, namely, the process of hand-sewing. Other portions of their work are laborious, but they are not of a character to produce much structural alteration. In sewing the boot the last is fixed firmly between the front of the chest and the upper aspect of the thigh, and the awl is used for making holes, through which the waxed threads are passed and then pulled tight. This pressure produced a marked alteration in the form of the thorax, which was so extreme that one would suppose that it must have been noticed through his clothes during lifetime.

On removing the skin and soft parts from the front of the chest, the lower portion of the sternum was found to form the floor of a deep concavity, below which there was on each side a large prominence, produced by the eversion and projection forwards of the sixth, seventh, eighth, and ninth costal cartilages.

The anterior surface of the gladiolus, and especially of its lower half, was covered by *a thick layer of dense fibrous tissue.* This was evidently produced by the blending of the *enormously hypertrophied anterior chondro-sternal ligaments* with those immediately adjacent on the same side, and with their fellows across the middle line. On cutting through this fibrous layer a subjacent layer of soft vascular tissue was exposed.

Crossing transversely, the front of the manubrio-gladiolar articulation was a similar, though separate, hypertrophy of the second anterior chondro-sternal ligaments.

On removing this there was exposed in the middle line a *vertical anterior manubrio-gladiolar ligament* of considerable strength, and possessing apparently but little elasticity. It was half an inch in breadth, and its margins were thick and well defined. It was attached above to the front of the manubrium, immediately above its lower limit, and below to a corresponding portion of the gladiolus. It crossed the centre of the manubrio-gladiolar articulation, and its fibres were rendered very tense when pressure was exerted upon the anterior surface of the gladiolus.

The *manubrio-gladiolar articulation* was very broad. It permitted

of no rotation of the manubrium around its antero-posterior axis upon the gladiolus, the articulation having been apparently converted into a *hinge-joint*, the manubrium and gladiolus moving upon one another only around a transverse axis, which passed through the joint connecting them.

The concavity formed by the anterior surface of the lower portion of the gladiolus occupied a vertical plane 2¾ inches behind that in which the extremities of the projections formed by the seventh, eighth, and ninth costal cartilages lay.

The xiphoid cartilage was completely ossified, and was connected by bone to the gladiolus. It was curved in such a manner that it prolonged the plane of the concavity of the anterior surface of the gladiolus, and its lower extremity was tilted forwards. It was narrow, but thick and strong, and on transverse section it was found to be triangular, the base of the triangle being directed forwards.

While the trunk rested in a supine position upon the table, the posterior sharp angle of the ossified xiphoid cartilage was separated from the front of the spinal column by an interval of 1½ inches, but when the body was placed in the sedentary attitude, the sharp posterior margin of this portion of the sternum was separated by a small interval of but ¾ inch from the spine. This small interval was occupied by the liver, diaphragm, and aorta, all of which appeared to be considerably compressed.

The second to the seventh costal cartilages presented very abundant osseous change, which increased in amount from above downwards, and was more extensive on the left side than on the right.

In the normal human subject the manubrio-gladiolar articulation performs two distinct functions, one of which is to permit of the rotation of the manubrium and first and second costal arches around an antero-posterior axis upon the gladiolus; the other is to allow of the gladiolus moving upon the manubrium around a transverse axis passing through the manubrio-gladiolar articulation. The manner in which this articulation is developed, the necessity for its existence, and the factors determining its evolution, I have discussed fully in previous papers.[1]

Now, in the shoemaker, the gladiolus sustained upon its anterior surface habitually an enormous amount of pressure. This resulted partly in the local change which this bone and the cartilages connected with it had undergone. It also produced an extreme flexion of the manubrio-gladiolar articulation, and rotated the manubrium very forcibly around a transverse axis passing through it. Owing to its very intimate attachment to the manubrium, the first costal arch sustained a very great strain, which tended to twist the first costal cartilages around an axis passing through their length, and to dis-

[1] "The Causation of some of the so-called Congenital Abnormalities and Variations," *Journal of Anatomy and Physiology*, 1887, &c.

place the heads and tuberosities of the first ribs upwards from their articulations with the body and transverse processes of the first dorsal vertebræ.

In consequence of the habitual presence of these powerful tendencies to the production of excessive movement, and with the evident object of opposing and limiting, the following very remarkable conditions resulted :—

The manubrio-gladiolar joint assumed the character of a hinge-joint, and permitted of movement of, the gladiolus upon the manubrium only around a transverse axis, and in order to limit excessive flexion of these bones upon one another a very powerful anterior manubrio-gladiolar ligament was developed.

The strain sustained by the first costal cartilages resulted in their very complete ossification, and though it was necessary that some joint should develop in the rigid cartilage, yet this joint was placed very obliquely, its outline was remarkably irregular, and the movements permitted in it were very limited. By the prolongation of its opposing articular surfaces downwards and inwards in an irregular manner, the movement of the manubrium around a transverse axis was still further limited, and resisted as much as possible. The habitual tendency to the upward displacement of the head and tubercles of the first ribs resulted in the considerable increase in the thickness of these ribs, in the strengthening of the costo-transverse articulations, and in the formation of cup-shaped cavities for the heads of the first ribs, similar in character to those I found in the coal-trimmer,[1] in which the tendency to upward displacement of the heads of the first ribs, which determined the development of the cup-shaped articular cavities, resulted almost entirely from the functions performed by the shoulder girdles.

The pressure sustained by the front of the chest, besides producing a change in the form of the sternum, produced a remarkable limitation of movement in the costo-vertebral articulations. This was most marked in the case of the sixth ribs, which were anchylosed to the bodies and transverse processes of the vertebræ, with which they originally articulated. It was also sufficient to limit very considerably, if not to prevent completely, any movement of the upper half or more of the chest during respiration. It would appear that, under these circumstances, the diaphragm performed nearly the whole of the function of filling the lungs with air; in fact, respiration was then purely diaphragmatic.

The proportion which is normally borne by the muscular and tendinous constituents of the diaphragm to one another was materially altered in this subject. The muscular portion was remarkably thick, and encroached very considerably upon the area which is normally tendinous. Thick bundles of muscle fibre projected prominently from the under surface of the muscular layer.

·. [1] "A Remarkable Instance of the manner in which Pressure-Changes may enable us to determine the Labour-History of the Individual," *Journal of Anatomy and Physiology,* 1887.

The pressure sustained by the soft structures which intervened between the xiphoid cartilage and spinal column resulted in much change in their form and relative positions to one another, and to the thoracic parietes.

The liver was displaced downwards by the apposition of the anterior and posterior walls of the chest, the pressure exerted by the xiphoid cartilage having severed almost completely the right from the left lobe of the liver. The left lobe, so separated, bore an abnormally small relation to the right.

The separation of the upper concavity into two separate domes caused the right lobe of the liver to be crushed up laterally into the right one, this compression resulting in the formation of the three antero-posterior grooves upon its upper surface. *The obvious mode of production of the fissures in this liver proves that fissures in the liver can be produced by pressure acting upon it either directly or indirectly.* It seemed that the nipping of the liver and other soft structures between the xiphoid cartilage and spinal column rendered the arch of the diaphragm very tense in the middle line, and by pulling upwards upon the conjoined crura it diminished the calibre of the orifice for the aorta, and so constricted this vessel at this point, and produced the dilatation of the thoracic aorta.

Or it is possible that the pressure which the third piece of the sternum exerted upon the diaphragm, where it covered the lower portion of the thoracic aorta, might have rendered the aortic orifice more oblique and its antero-posterior diameter correspondingly less. That the resistance which was offered at this point to the passage of blood was considerable was shown by the considerable and abrupt diminution in the calibre of the vessel, though no branch had arisen between the points at which it was measured, and by the abrupt line presented by the atheromatous change in the walls of the artery.

On removing the diaphragm and front of the chest, and exposing the aorta, that vessel was seen to be abruptly dilated above the aortic orifice in the diaphragm. Although no large branch came off between the points measured, the diameter of the lower extremity of the thoracic aorta was $1\frac{3}{16}$ inches, and that of the upper extremity of the abdominal aorta $\frac{15}{16}$ inch, the diameter of the thoracic aorta showing an excess of $\frac{1}{4}$ inch. The position of the margin of the aortic orifice in the diaphragm was indicated upon the aorta by an abrupt transition from an opaque white colour, which was presented by the lower $2\frac{1}{2}$ inches of the thoracic aorta, to the colour presented by the abdominal aorta, which appeared to be quite normal. The opacity of the coat of the thoracic aorta blended less abruptly above with the upper portion of the thoracic aorta, whose colour resembled that of the abdominal aorta and other large vessels.

The cœliac axis came off from the left portion of the anterior aspect of the thoracic aorta nearly $\frac{3}{4}$ inch above the aortic ring, and it passed with the aorta through the same aperture in the diaphragm. A calcareous atheromatous plate in the wall of the aorta surrounded the orifice of the cœliac axis, and that vessel itself appeared to be

dilated, while its walls were opaque and atheromatous. The branches of the cœliac axis below the diaphragm were apparently quite normal.

On placing the body in the sedentary posture it was observed that the convex sharp margin of the xiphoid cartilage pressed upon the opaque portion of the thoracic aorta.

On opening this vessel the inner coats of its lower portion pre sented a considerable amount of atheromatous change, which was most marked in and about the origin of the cœliac axis. Similar, though less marked, degenerative changes were present in the abdominal aorta.

The upper portion of the thoracic aorta showed very slight atheromatous deposit.

The heart was not large. There was a considerable amount of fat surrounding it; but it was impossible to determine whether the muscular fibre had undergone any fatty degeneration or not.

At first sight the changes which were presented by the trunk and the head and neck appeared very complex indeed.

If one were not already very familiar with the extensive and remarkable changes in form which bones will undergo when they are subjected habitually for a long period of time to the influence of a tendency to produce certain changes in form, one would have felt inclined to relegate some of the conditions which this spinal column presented to that ill-defined class comprised under the terms *congenital abnormality* or *deformity*. I refer to such changes as the prolongation upwards of the transverse process of the atlas and its articulation with the jugular process of the occipital bone. I have seen the beginning of this condition on two previous occasions. However, with the exercise of a little perseverance in the study of the changes of a transitory nature which this portion of the body undergoes in different attitudes, the causation of these phenomena, which were at first very obscure, became clear and well defined. The reader will best see the manner in which the fixed and exaggerated conditions presented by this body were produced by assuming the sedentary posture of the shoemaker while engaged at his work. Let him then fix firmly a last between the chest and the upper aspect of the right thigh, and while he retains the article in this position let him think out carefully what position the several portions of his column, the head, thorax, and pelvis, are occupying. He will then be able to ascertain that the anatomy of this shoemaker represents

simply the fixation and subsequent exaggeration of the position and tendencies to change which were present in his body when he assumed the position for a short period of time.

He will find that, in order to exert a suitable and sufficient pressure upon the last and boot, he will rotate his thorax around a vertical axis, as well as around an antero-posterior one. He will throw the left chest forwards, at the same time depressing it, and the right chest backwards, raising it a little also. He will feel that the lower true costal cartilages on the left side transmit a larger proportion of the pressure than those on the right.

In consequence of this position assumed by the chest, the dorsal spine forms a curve with its convexity to the right, while its normal curvature in an antero-posterior plane is slightly increased. This portion of the column is fixed, since the pressure exerted by the last upon the sternum and costal cartilages, and the muscular action brought to bear upon the thorax, in order that it may support this pressure, practically renders it so.

In order that the thorax may be brought into such a vertical level as regards the right thigh, that it may be able to fix the last upon it, it becomes apparent that the fixed dorsal spine is rotated upon the pelvis and lumbar spine by means of a vertical rotation of the last dorsal vertebra upon the first lumbar, of the first lumbar upon the second, and probably in a diminishing degree to the fourth and fifth, since the fifth lumbar does not rotate upon the sacrum around a vertical axis; also, that the normal anterior convexity of the lumbar curve is diminished, the anterior portions of the lower, and especially the lowest, fibro-cartilage being compressed, and a tendency to the forward and downward displacement of the lumbo-sacral articulation being present. Since the sacro-iliac synchondrosis is flexed, there exists a tendency to the induration or the partial or complete removal of the fibro-cartilage where it is compressed between the opposing surfaces of bone drawn violently together by the tightly drawn fibres of the posterior sacro-iliac ligaments, and by the ligaments and fibro-cartilage of the pubic symphysis. The lumbar region must also present a lateral curve, whose convexity is to the left, and the upper extremity of this convexity, since it prolongs the concavity of the dorsal region, must lie to the

right of the middle line of the body, as represented by that of the sacrum and pelvis.

The concavity of the lumbar curve is directed to the right. Now, as far as the transmission of pressure is considered, the concavity of the lumbar curve cannot be regarded as being limited to that region, since the right thigh is fixed by the tonic contraction of powerful muscles to the right innominate bone, and the innominate is drawn vigorously to the lumbar spine and right chest; therefore, we must consider the concavity of this arch as being formed by the lower half of the convexity of the dorsal spine, the concavity of the lumbar spine, the upper portion of the body of the sacrum and its lateral mass on the right side, and the innominate bone. Practically, the symphysis pubis may be fairly regarded as forming a portion of the concavity of this arch.

The fibro-cartilages, which enter into the formation of this concavity, must be compressed by the considerable amount of pressure transmitted along it, so that there exists a tendency to their destruction, and to the lipping and subsequent ankylosis of the margins of the adjoining bones.

It is obvious that, as a considerable amount of movement around a vertical axis takes place between the comparatively fixed dorsal spine and the upper lumbar vertebræ, ankylosis will not take place in this region, but that the fibro-cartilages connecting the bodies, and the form and extent of the articular surfaces covering the articular processes of these vertebræ, will be altered in order to allow of free rotation. There will, however, exist a tendency to the increase of the opposing areas of the bodies of the vertebræ, especially in the direction in which rotation takes place by means of the marginal deposit of bone.

In the case of the lowest lumbar and lumbo-sacral articulations, the tendency to the destruction of the fibro-cartilages in the concavity of the curve is still greater; and again in the lower dorsal articulations and in the right sacro-iliac synchondrosis, owing to the comparative fixity of these structures, the tendency to fusion is very much stronger.

It is apparent that both in the movement of flexion of the sacro-iliac joint, and in that attitude which may be regarded as one of abduction of the ilium upon the sacrum, there must exist

a strong tendency to the separation of the two pubic bones, both in a horizontal and in a vertical plane. This tendency, if habitually exerted, would lead to an increase in the strength of those ligaments which oppose it.

In sewing the boot the head is held well forwards, directly above the work, on the right thigh. On this account the anterior convexity of the cervical spine is diminished by the compression of the front portions of the fibro-cartilages. The occiput is also flexed upon the atlas, and the transverse ligament and check ligaments sustain much strain. There is also developed a well-marked lateral curve, whose convexity is directed to the left. This curve occupies the upper dorsal and nearly the whole of the cervical region, and the amount of compression sustained by the fibro-cartilages, where they form a part of the right antero-lateral aspect of this portion of the column, is greater than it is in the antero-lateral surface, which corresponds to the convexity of the curve.

Since the head is retained vertically, or nearly vertically, as the base of the skull looks downwards and slightly to the right, the occipital bone and the upper three or four cervical vertebræ form another lateral curve, whose convexity is directed to the right. There must exist, then, a considerable compression of the left antero-lateral portion of the fibro-cartilage, which connects the axis and third cervical vertebra, and to a less degree of that connecting the bodies of the third and fourth.

Owing to the oblique position which the head assumes by performing a movement of rotation around an antero-posterior axis, as already described, and also to a varying and slighter degree around a vertical axis, there must exist a tendency to produce changes in the form of the condyles of the occipital bone and in the superior articular surfaces of the atlas; and these changes would work chiefly in the direction of increasing the areas of the articulating surfaces, and particularly of those on the left side.

I think that it is perfectly fair to assume that during the performance of this work there must also exist a tendency to the development of some formation upon or from the upper surface of the left portion of the lateral mass of the atlas, in order to support the superjacent portion of the base of the

skull, and so to counteract a tendency which is present to the excessive rotation of the head upon the atlas around an antero-posterior axis, by means of which very much strain is thrown upon the condylar joints, and the medulla placed in considerable danger.

There cannot, I believe, be any doubt that this is the explanation of the development of the new joint which was present between the strong process of bone, which projected upwards from the left portion of the atlas, and the under surface of the jugular process of the occipital bone.

This growth of bone developed in consequence of the existence of a tendency to its formation, or in other words, as the result of the existence of a demand or necessity for its presence in the same manner and for the same reasons that a similar bone formation extended outwards from the body of the first dorsal vertebra above the head of the first rib. As the occipital bone is habitually flexed upon the atlas, there also exists a tendency to the formation of a joint between the upper margin of the anterior arch of the atlas and the bone forming the anterior boundary of the foramen magnum.

As the shoemaker draws the threads, the head is, on account of its connection with the trunk by means of the cervical spine, thrown somewhat violently and suddenly forwards and down-wards. The changes which develop in the neck during this movement may be regarded as constituting a distinct sequence. It is obvious that the first thing to take place is a violent impaction of the odontoid process in a forward and upward direction against the anterior arch of the atlas, which, with the head, is not always retained in really the same angle of rotation around a vertical axis. In consequence of the habitual performance of this movement, there must exist the following progressive tendencies, namely, to the destruction of the articular cartilage, which covers the opposing surfaces of the odontoid process and arch of the atlas; to the eburnation of the exposed bone; to the excavation and increase in area of the facet on the atlas, both laterally and vertically, the tendency to the increase of the vertical diameter being upwards beyond the normal upper limit of the anterior arch; and to the corresponding and commensurate increase in the height of the odontoid process

by the deposit of bone along its upper limit. The sudden increase of the flexion of the cervical and upper dorsal spine, and especially of the adjacent portions of these two sections of the column, produced by the abrupt forward and downward movement of the skull, develops a very strong tendency to the formation of an excessive amount of marginal bossing and anchylosis of the margins of the bodies of the vertebræ, since the conditions are quite distinct from those in which pressure, however considerable, is transmitted steadily through bones and fibro-cartilages. They correspond rather to those which are present in the case of such fractures as are mended by that form of callus which is technically described as *provisional*.

A great amount of dense bone, which was present in the anterior surface of the cervico-dorsal region of the column of the shoemaker, was obviously dependent for its causation upon these mechanical conditions.

The joints in the centre of the cervical region escaped any considerable lateral destruction, for the reason that the bodies of these vertebræ did not form a very prominent portion of the lateral curve, and because the abrupt primary movement of the column and the equally sudden movement of the skull in an antero-posterior place necessitated a certain freedom of movement in this region around a transverse axis.

I will not weary the reader by describing all of the very numerous changes which the spinal column and pelvis of this workman had undergone in consequence of the existence of the tendencies I have related. It is sufficient to state that they were such as one would expect to find in *a priori* ground. I must, however, describe briefly the conditions presented by the upper portion of the cervical column and by the occipital bone, since they were unusual in character.

The left half of the body of the axis, as is shown in Pl. XIX. fig. 3, was in great part united by bone to the corresponding portion of the body of the third cervical vertebra. The articular processes, laminæ, and spinous processes of these vertebræ were on the left side connected by bone. This fusion of the laminæ had obviously not resulted from the forcible opposition of these portions of the vertebræ, but represented apparently an ossification of the ligaments connecting them. There was some similar growth on the right side, but it was much less abundant than on the left. The position of the original joint between the articular processes of these vertebræ was indicated by the presence of a

prominent oblique elevation.   There was some bossing of the margins
of the articular processes of the vertebræ immediately below on the
same side, namely the third and fourth.

The odontoid process was peculiarly modified in form.   Its height
was increased by the projection upwards from the anterior portion of
its upper extremity of a thin curved plate of dense bone.   Both this
additional process of bone and the adjacent portion of the odontoid
process presented upon their anterior surface a continuous densely
eburnated polished facet, which was convex from side to side.   It
was subdivided into two portions which occupied different vertical
places, that on the normal odontoid process lying in front of the one
above it.

There was a large vertically oval facet on the back of the odontoid
process.   This was covered by articular cartilage, and articulated
with an abnormally well-developed transverse ligament.   Its surface
was convex from side to side, and encroached slightly upon the
lateral aspects of the process.

The remainder of the bone was rough for the attachment of
check ligaments, which were also very well developed.

An accessory transverse ligament, which was attached to tubercles
immediately internal to the anterior portions of the condyles of the
occipital bone, lay in front of the check ligament and behind the
upward prolongation of the odontoid process.   It was apparent that
it performed a function similar and accessory to that of the normal
transverse ligament.   This structure I have indicated in fig. 2.   The
atlas presented three distinct variations, one of which at least was
very remarkable.   The condylar facets on its upper surface were
unequal in extent, the left being longer from before backwards; a
prominent little knob of bone projected upwards, backwards, and
outwards from the posterior limit of this facet.

The anterior arch was deeply excavated posteriorly.   Its depth
was nearly doubled by the deposit of bone upon its upper and lower
margins, the amount of new growth above being very abundant, while
that below was scanty.   The large cup-shaped facet occupied the
whole increased depth of the arch.   Its surface was highly polished
and densely eburnated.   It was subdivided into two parts by a slight
ridge which ran transversely across its surface.   On articulating this
bone with the axis, the facet described on the anterior surface of the
odontoid process, and upon its upward prolongation articulated with
the two parts of the atloid facet.   Its upper margin was very
irregular, and overhung the floor of the cavity.   On articulating the
atlas with the occipital bone, the irregular upper margin of the atloid
facet fitted into and occupied an irregular narrow groove with
prominent edges upon the under surface of the anterior margin of
the foramen magnum.   This I have tried to illustrate in fig. 2.   From
the upper surface of the transverse process of the atlas immediately
outside and behind the vertical foramen, there projected vertically
upwards a strong process of bone which was flattened from side to
side.   Its extremity was broad, and presented a quadrilateral rough
facet upon its upper surface.   This articulated with a corresponding

depression on the under surface of the jugular process of the occipital bone immediately internal to the groove which attaches the posterior belly of the digastric muscle. A small synovial cavity surrounded this acquired articulation, but there was no appearance of a capsular ligament. This process of bone and the increased depth of the anterior arch are shown pretty clearly in fig. 1.

As the head is thrown forwards with considerable violence, and especially at the termination of this forward movement, the odontoid process exerts a very great strain upon the transverse and check ligaments. The presence of this strain tends to produce the better development of these structures which oppose the backward displacement of the process of the axis.

We find here in this shoemaker, whose anatomy I have described, another remarkable instance of the manner in which the organism will provide, almost as if by instinct, if I might so use the term, a structure which is definite in its form and in its capacity for performing a certain function in response to a tendency or a necessity for its existence. I refer more particularly here to the additional transverse ligament which lay behind the upward prolongation of the odontoid process, and was attached on either side to the margin of the foramen magnum, and which opposed its backward displacement. It is quite obvious that this transverse ligament could not have existed before the odontoid process was prolonged to its level, and that it appeared and performed its function only when the necessity for its existence arose. Its development is but one instance of a law which is abundantly illustrated by the anatomy of this subject. It is difficult to understand the exact manner, and from what such a definite structure is developed. The higher mammals are unable to reproduce portions of their body which are destroyed or injured. *They possess, however, a much more remarkable power, which, I think, is the most important factor in evolution.*

It is that they are able to produce, in response to a tendency to its development, which tendency has arisen in consequence of the individual being subjected to the influence of mechanical forces other than those that determined his evolution, a more or less complete change in the character of the anatomy and physiology of a part or of the whole of their bodies.

If it is impossible for this tendency to result in its actuality

during the lifetime of that individual, it is able to transmit that tendency to change to its offspring, in which it may produce the actuality.[1]

I recently applied this law to explain the changes which the skeleton undergoes in abnormal conditions, as mollities ossium, rickets, osteitis deformans, and congenital syphilis; and I was able to satisfy myself completely on its applicability to this subject.[2]

While sewing, the thighs are flexed upon the trunk and are retained firmly in this position, in order to retain the boot and last in position, by the exercise of a considerable amount of muscular energy. By this means the upper surface of the head of the femur is retained in firm contact with the back part of the acetabulum, so that there exists a certain tendency to the displacement of the head directly backwards. In response to this tendency there is developed on the posterior margin of the acetabulum a sharp prominent ridge of bone, and the cotyloid ligament is prolonged outwards over this.

I had never before seen such a growth of bone and fibro-cartilage upon this portion of the acetabular margin, though it is readily developed, and is frequently present in response to a similar tendency upon the upper or upper and posterior portions of the margin of the cavity in many occupations, and in morbid conditions in which the trunk is retained in a position of flexion upon the thigh.

Owing to the habitual and considerable flexion of the hip-joint, and the consequent apposition of the articular surface of the acetabulum with the non-articular portion of the neck of the femur, the articular surface of the head had been prolonged downwards and outwards over the neck by the direct conversion of the synovial membrane into articular cartilage and bone. The appearance presented by these extensions of articular cartilage upon the neck of the femur vary considerably and definitely with the cause which determines their production, and one might write a great deal about them. As in most

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[1] " Can a Tendency which produces no Change in the Parent result in the actuality of the Change in the Offspring," *Journ. of Anat. and Phys.*, 1887.

[2] " The Factors which determine the Hypertrophy of the Skull in Mollities Ossium, Rickets, Congenital Syphilis, and Osteitis Deformans," *Proc. Roy. Med. Chir. Soc.*, 1887, and *Lancet*, May 1888.

sedentary occupations, bursal cavities of considerable size had developed in consequence of the habitual pressure sustained by the tuberosities of the ischium.

The changes which the shoulder girdles undergo in this occupation are very definite and characteristic.

After the hole has been made in the leather by means of the awl, the waxed threads are passed through it. Their ends are then grasped firmly in the hands, one being usually twisted round the awl held in the right hand, while the other is made to encircle the palm, which is guarded from injury by a suitable leathern shield.

By means of a sudden and violent jerk the shoemaker pulls the threads through the hole, and by abducting and extending his shoulder-joints he continues to separate his hands till he has pulled through the whole of the slack. He then gives the threads an additional jerk, expending, as in the first movement, a great deal of muscular energy.

It would be impossible to pull the threads through the hole made by the awl without applying to them the sudden initial strain. It is therefore apparent that the greatest amount of energy is expended upon the commencement of the movement, though throughout it all much force is exerted.

Since the right upper extremity is used in performing some movements in addition to those performed by the left, we would expect to find in the right shoulder-joint less exactly defined indications of a single succession of movements than on the left side. I refer to such movements as hammering, polishing, &c. It is apparent, from a little consideration, that these movements can tend to produce but very slight modifications in the characters of the bones and joints, as compared to those which must result from the habitual performance of the sewing movement for a long period of years. If we analyse the mode and direction by which force is transmitted from the upper extremity to the sternum and first costal arch in this movement in order to determine the tendencies to change which are developed during its performance, we see that at its commencement the clavicle occupies a position of slight flexion and adduction upon the manubrium and first costal arch, and that at its termination it is in a position of extreme extension and abduction. The outer

extremity of the clavicle has passed in a straight line, running from below, upwards and backwards, its inner extremity moving upon the sternum around an axis, whose direction is from above, downwards and backwards. Since this is the only movement which takes place habitually in the sterno-clavicular articulation, it becomes for all practical purposes a hinge-joint, and the opposing surfaces of bone tend to assume the form most useful for the performance of such movements, a tendency existing to the increase of the size of the inner extremity of the clavicle and of the area of the articular cavity formed by the manubrium and first costal cartilage; to the excessive elongation of the inner extremity of the clavicle in the direction of the axis of rotation; to rendering the inner surface of the clavicle convex in a direction which crosses the axis of rotation at right angles, namely, from above, downwards and forwards, and to changing the form of the costo-sternal facet, that it shall accommodate the inner extremity of the clavicle in its altered form.

In drawing the threads the clavicle forms the resultant of a parallelogram of forces, one acting in a direction from without, downwards, forwards, and inwards, and corresponding to the resistance which the leather offers to the passage of the waxed threads, and the other in a direction from without, upwards, backwards, and inwards, and corresponding to the strain exerted by the trapezius, levator anguli scapulae and rhomboid muscles, as they draw the scapula and the outer end of the clavicle upwards, backwards, and inwards.

Though the general direction of the force which is transmitted along the clavicle during the whole of the movements is inwards, yet the exact direction varies considerably at different periods of the movement.

For instance, at the commencement of the movement, when the clavicle is transmitting the greatest amount of pressure, the direction which it takes is upwards, inwards, and backwards, so that there exists a tendency to the displacement of the inner end of the clavicle upwards and backwards; to the destruction of the fibro-cartilage where it intervenes between the anterior portion of the inner end of the clavicle and the sternum, and of the articular cartilage covering the thin opposed surfaces of clavicle and sternum; and to the hypertrophy of the ligaments,

which oppose such a tendency to displacement of the sternal end of the clavicle. These ligaments are the posterior and upper portions of the capsular ligament and the interclavicular.

At the end of the movement the clavicle is transmitting pressure to the sternum in a direction from without, inwards, forwards, and downwards, so that there exists at this period a tendency to the destruction of the posterior and upper portion of the interarticular fibro-cartilage where it intervenes between the posterior and upper part of the facet on the clavicle and the sternum; to the removal of the articular cartilage covering the articular surfaces of the clavicle and sternum, which come into immediate apposition after the destruction of the intervening fibro-cartilage; also to the eburnation of the exposed bone; to the hypertrophy of the ligaments opposing the movement, and possibly to their elongation, if the movement performed be extreme, as it is in this case, and the ligaments showing this change are the anterior sterno-clavicular and rhomboid ligaments, the costo-coracoid membrane, and the subclavius, much of the substance of which tends to retrocede under the influence of the strain it experiences; to the displacement of the inner end of the clavicle forwards and downwards, and to the elevation of the anterior margin of the chondro-sternal facet, in order to oppose this displacement.

In an intermediate position of the movement between these two extremes the pressure is transmitted almost directly inwards along the clavicle, and the tendency to produce definite and similar changes is quite obvious.

The influence of the very considerable amount of force which is exerted inwards along the direction of and by means of the clavicle, added to the movement of the outer extremity of the clavicle in an oblique plane around an axis which passes at right angles to that plane through the sterno-clavicular articulation, tends to exert a very powerful influence, and finally results in the conversion of the very complex arthrodial sterno-clavicular joint into the joint of the aged shoemaker, which may be regarded as almost a perfectly ginglymoid articulation. The inner extremity of the clavicle had completely lost its normal form. It was enormously increased in size, and formed an oval extremity whose long axis ran from above downwards and

slightly backwards. This diameter of the inner end of the clavicle measured 1¾ inches, while its breadth was under an inch.

The structure of the sterno-clavicular articulation as a normal and permanent mechanism is remarkably ill adapted to the performance of heavy muscular labour. When it is subjected habitually to any great strain for a long period of time, it undergoes very extensive changes at a comparatively rapid rate, and the variations which are developed vary within wide limits with the form of the occupation, and therefore with the character of the laborious movements which this joint is called upon to perform habitually.

We will take, for instance, that portion of the joint which, from its definite form, structure, and attachments, shows most distinctly any alteration. I have examined a great many sterno-clavicular joints in labourers, but have never seen one in which the fibro-cartilage had been so completely removed as it had been in this shoemaker, nor in which the inner end of the clavicle and the chondro-sternal facet had undergone such extreme and remarkable changes in form and character; there is, however, not the slightest difficulty in understanding the manner in which this complete change was brought about by the habitual movements of this workman.

The nearest approach to it which I have observed was in the body of a powerfully-built sailor. In that case the fibro-cartilage had lost its attachment to the clavicle as well as to the sternal portion of the joint. The only relic of the original structure was a densely-fibrous wedge, containing minute particles of bone scattered through its substance. This was attached to the upper portion of the capsule of the joint by its base, and, projecting downwards, occupied the angular interval which existed between the two bones above. I have indicated this in fig. 6. We are aware that the sailor performs a great many movements of different kinds with his arms, in which he exerts a considerable amount of muscular energy. Yet, though they would seem to form a very complex group, I think we can at once separate from them all those in which an immense amount of strain is thrown upon the sterno-clavicular articulation. The other movements, as climbing, &c., may demand the expenditure of

much muscular exertion, but in them the sterno-clavicular articulations do not transmit the same amount of pressure. I refer particularly to two movements, one in which an immense pressure is exerted in a forward and downward direction upon the outer end of the clavicle, which occupies a position of flexion and adduction at its sternal articulation, and resting upon the first cartilage, as in pulling upon a rope which passes through a pulley on a level with the deck. In the other movement a corresponding amount of pressure is exerted upon the outer part of the clavicle in a backward and downward direction, that bone being extended completely upon the sternum, and resting upon the first rib. This takes place when the man hauls in a rope which passes from behind over his shoulder. There are many other similar movements in which force is exerted upon the clavicle, either in these directions and positions, or in intermediate ones, but the two extremes which I have given serve to illustrate my point. In the first the anterior portion of the lower half of the fibro-cartilage intervenes between the surfaces of clavicle and sternum through which the force is transmitted, and it is rapidly destroyed ; while in the second movement the posterior half of the lower section of the fibro-cartilage is compressed and finally obliterated. The dense wedge of partly ossified fibro-cartilage which remains serves a certain, obvious, definite, and useful purpose. I might describe the varied conditions of this joint which are present in very many forms of labour, since in every one who has performed habitually any kind of heavy manual exercise some change is always present. I think, however, that the examples of the shoemaker and sailor serve to illustrate sufficiently fully and clearly for the limits of this paper the truth of my statement.

Owing to the exact similarity of the movements of the two arms in sewing, each clavicle must impinge upon the same spot upon the costal arch. In consequence of this, one would expect to find but a very small chondro or costo-clavicular articulation present in the substance of the rhomboid ligament, and the opposing articulating surfaces very small and well-defined. The large amount of pressure which the clavicles exert upon the first costal arch, together with the necessity of the fixation of the arch as regards any rotation of it or of the manubrium

around an antero-posterior axis, would assist materially in producing an early ossification of the first costal cartilages, in the development of strong amphiarthrodial joints in their substance, and in rendering the manubrio-gladiolar articulation rigid as regards movement of the manubrium upon the gladiolus around any but a transverse axis.

Nearly the whole of the force which is transmitted in an inward direction by the clavicle to the costo-sternal articulation must be applied to the outer end of the clavicle by the acromion process of the scapula.

Therefore, it is quite obvious that there must exist two tendencies to produce change in the form of this bone, which normally presents two curves in the same plane. One tendency is to produce a local change. By that I mean an alteration in the direction, form, and character of the acromial facet, and in the shape of the bone immediately adjacent to it. The second tendency is to increase the curvatures of the clavicle, and so render it shorter.

Many points of extreme interest and importance arise in connection with the discussion of the results produced by these tendencies.

In the normal acromio-clavicular articulation, as it exists in the young subject, the plane of the opposing surfaces forms nearly an equal angle with the vertical and the horizontal planes; in most cases the former is a little the smaller. In many of the quadrumana which I have dissected, I have found that the plane of the opposing facets formed with the horizontal plane a similar angle.

The great advantage of such a joint in this situation is particularly obvious in these animals, since they are so habitually engaged in supporting themselves by their upper extremities. While in this attitude there exists a tendency to the separation of the opposing articular surfaces, so that if they were vertical and were separated in consequence of the strain exerted upon the joint, a vacuum must be formed between the bones. By means, however, of the obliquity of the plane of the facets, the joint can be extended very considerably without the formation of any vacuum between the bones, or in any way limiting the freedom of movement or diminishing the security of the forcibly

extended joint. The same mechanism is again made use of in the sterno-clavicular articulation in many of these small quadrumana, where it serves the same useful purpose, giving remarkable freedom of movement and strength and security to the joint. The anatomy of these joints in man and in quadrumana will, I hope, form the subject of a future communication, in which I hope to discuss very fully the factors which determine the several variations they present.

I will at present restrict myself to saying that the normal condition of the acromio-clavicular articulation is extremely ill-adapted to the performance of any laborious occupation, so that it at once undergoes a complete change when such work is engaged in.

In the normal joint I have been unable to find any fibro-cartilage present. Its development I will show to be what I might term a " suction change," due to factors other than those which determined the form of the so-called normal condition.

In association with the movement of abduction and extension of the shoulder-joint, the scapula undergoes a movement upwards, inwards, and slightly backwards, but it also apparently rotates slightly upon an antero-posterior axis. The outer end of the clavicle follows the acromion in its movement, chiefly on account of its connection to it by ligaments, the trapezius also influencing it considerably in doing so. The normal obliquity of the opposing facets must therefore be replaced at an early period of the individual's labour history by articular surfaces lying in a vertical plane. Since the acromial facet moves from before backwards upon the clavicle in the form of an arc of a circle, and since the pressure sustained by the opposing surfaces of clavicle and acromion is greatest at the commencement of the movement, the facet on the clavicle is larger and deeper than that upon the acromion, it is slightly convex from before backwards, its anterior portion is much more polished and eburnated than its posterior part, and the deposit of bone upon its upper margin and upon the adjacent surfaces of the clavicle is much more abundant than upon its lower. The facet on the acromion is smaller, and is slightly concave from before backwards. These local changes in the outer extremity of the clavicle are illustrated remarkably well by the anatomy of the shoemaker.

In the normal acromio-clavicular joint there is a very strong superior ligament, which is attached to the upper surface of the posterior margin of the outer extremity of the clavicle. The fibres forming this ligament run forwards and outwards to the upper surface of the acromion process. The structure of the remainder of the so-called capsule of this joint is very thin. In this case there did not exist a tendency to the displacement of the acromion in a forward and downward direction, as in the normal subject when the arm is hanging by the side, but there was developed a tendency to its displacement upwards and backwards. In consequence of the presence of this tendency, the character of the ligaments of this joint changes, and the direction of the fibres of the superior ligament was altered, and a thickening was formed in the lower portion of the capsule in what may be regarded as a well-developed specimen of the genus shoemaker.

At the end of the movement of abduction and extension of the humerus at the shoulder-joint, and to a less extent throughout the whole of it, the scapula bears to the clavicle, in its articulation with it, a position the reverse of that which it occupies in extreme flexion of the shoulder-joint. I have described the latter relationship in a paper[1] which I read recently before the Royal Medical Chirurgical Society, in which I showed its importance from a surgical aspect. The former relationship we may fairly describe as one of extension. In this position the upper portion of the root of the coracoid process, namely, the surface immediately in front of the conoid tubercle, comes continually into contact with the under surface of the clavicle, the conoid ligament is retained in a condition of relaxation, and the trapezoid ligament in a state of habitual compression. In consequence of this, the conoid ligament becomes short, and forms part of the capsule of a coraco-clavicular articulation which is developed in this situation, while the atrophied trapezoid ligament remains in the cavity of this joint.

I have never, except in the case of the shoemaker, seen a coraco-clavicular articulation developed on this portion of the

[1] "A Mode of Fixation of the Scapula, and its bearing upon the Mechanism of Fracture of the Coracoid Process," *Proc. Roy. Med. Chir. Soc.*, 1887, and *British Medical Journal*, May 19, 1888.

coracoid process. The explanation is, that in no other occupation which I have had an opportunity of examining has the scapula been retained habitually in such a position of extension upon the clavicle. In a large number of labours, however, the scapula is retained in a position of forcible and extreme flexion upon the clavicle, and this accounts for the frequent presence of a joint in relation with the anterior portion of the upper surface of the coracoid process.

As regards the result of the second of the two tendencies which exist, namely, to produce a shortening and increased curvation of the clavicle, I have but little doubt that the habitual exercise of a considerable force, such as that present in the shoemaker, is sufficient to produce, at least during young and early adult life, some such considerable change in the general form of the bone as was present in this subject.

We see a similar change in the form of the long bones of the lower extremity under the influence of habitual pressure in the case of children who ride constantly bare-back; or in the flat bones, as in the shoemaker's sternum. At the same time, I think we must allow that the extent of the change in form bears direct proportion to the loss of tone and vigour by the individual.

In the case of the shoemaker it is particularly difficult to measure the exact amount of increased curvature which is due to the exercise of this pressure, for another factor is present which complicates the problem very considerably. This is, perhaps, not quite so apparent and distinct in the case of the clavicle as I think I can make it in that of the scapula. It is an instance of what should be a well-known law, but one which does not receive the attention it deserves, nor is it applied as frequently or as generally as it ought to be. *It is that, in proportion as a muscle is exposed habitually to constant and considerable strain, in the same proportion do its muscular fibres tend to retrocede to tendon, and the bony surfaces into which it is inserted tend to grow in the direction of the traction which the muscle exerts upon them.* In the case of the clavicle, I refer particularly to the whole of the insertion of the trapezius into it, and to a portion, namely, the outer, of the clavicular attachment of the deltoid.

The same principle is illustrated in this subject by the sub-clavius muscles, which were so habitually exposed to considerable and sudden strain. Much of the muscular fibre of these muscles had retroceded, if one might so apply this term, to tendon, liga-ment, and fascia. Since, in the movement of sewing, the extremity of the coracoid process is not separated more than normally from its costal attachment, but is, on the contrary, approximated to it, the thickening which is frequently present in the costo-coracoid membrane was not obvious in this subject, for the reason that there existed no necessity for its existence or tendency to its development.

Now, let us attempt to apply the law which I have just formulated to the case of the scapula of the shoemaker. In the movement of the arms in sewing the boot, the scapula is drawn upwards, inwards, and backwards in an oblique plane, the bone undergoing but a slight degree of rotation around an oblique antero-posterior axis.

Since this movement of the scapula is opposed by the very considerable resistance which the leather affords to the passage of the waxed threads through it, the amount of force exerted by the muscles which produce this movement of the bone must be very great. The muscles are the trapezius and rhomboids, and to a very slight degree the levator anguli scapulæ. We would therefore expect to find, in one who habitually performed this labour, that the surfaces into which the trapezius and rhomboid muscles were inserted were very thick and prominent, and in the case of their being marginal, that they were prolonged in the direction in which traction was exerted upon them. This was very marked in this subject. I have indicated in outline, in figs. 7 and 8, many of the most conspicuous characters of the right scapula.

The insertion of the trapezius was very broad and con-spicuous, and its large area served to assist in producing abnormally great breadth of the posterior free margin of the spinous process. The inner margin of the scapula formed two prominent convexities, which were developed in the direction of the traction exerted upon that border by the rhomboid muscles.

The humerus is moved upon the scapula from a position of

adduction and partial flexion to one of extreme abduction and of considerable extension. As this movement is violently opposed, a great amount of force must be exerted by the muscles which produce it, and a corresponding amount of strain must be experienced by the portions of the bones into which these muscles are inserted.

The muscles which are chiefly engaged in performing the movement are the supraspinatus and the central and posterior portions of the deltoid. The anterior portion of the latter muscle takes a minor share in the production of the movement. The influence of the traction exerted by the supraspinatus upon the scapula is indicated by the very considerable eversion of those margins of the scapula into which its muscle and aponeurosis are inserted, namely the whole of the upper and that portion of the inner which is above the level of the spinous process. I have endeavoured to represent in fig. 8 a view of the vertebral margin of the scapula as seen from the middle line of the body, and by means of the dotted line I have indicated the outline of the venter of the scapula, corresponding to the floor of the supraspinous fossa. Besides showing the great depth and extent of this fossa, it also gives some idea of the amount of eversion of its vertebral margin. In the same manner the traction exerted by the supraspinatus upon this margin had so influenced the position of the upper angle of the scapula, that the angle which is enclosed between a line joining the upper angle and the inner limit of the spinous process, and one joining the latter point and the lower angle of the scapula, is abnormally small.

The strain exerted by the deltoid upon its scapular attachment has resulted in the enormous increase in the antero-posterior measurement of the free outer margin of the acromion, which has developed in an outward and backward direction, and it has assisted in the production of the great breadth of the posterior free margin of the spinous process.

The spinous process and acromion showed a greater increase in size than any other portion of the scapula. The breadth of the posterior margin of the spinous process measured at two points $\frac{5}{8}$ and $1\frac{1}{4}$ inches respectively, the measurements of the corresponding points in an average scapula being $\frac{1}{2}$ and $\frac{15}{16}$ inch. The outer margin of the acromion measured $3\frac{1}{8}$ inches as compared to an average measure-

ment of 1¾ inches. The plane of the clavicular facet was vertical, its area was enormously increased, and its surface was densely eburnated. The insertion of the deltoid into the humerus was indicated by the presence of a mound of rough bone which was very much larger than anything I had ever seen in this position.

A consideration of the direction in which force is exerted by that portion of the deltoid which is chiefly engaged in the performance of the movement of abduction and extension of the humerus, and the mechanical advantages which such a prolongation of the acromion affords, renders obvious the manner in which the acromion has altered its form in response to the tendency to such a change which is habitually present.

Perhaps I can best illustrate some of the changes in form which the scapula undergoes by describing very briefly the chief characters which it presents in another form of labour, in the performance of which a different set of movements are carried out and force is exerted along somewhat different directions.

Fig. 9 represent the posterior surface, and fig. 10 the vertebral margin of the scapula of a labourer, who had apparently been engaged habitually in carrying loads of considerable weight upon his right shoulder. In order to render the comparison as complete as possible, I have chosen a subject of about the same age as the shoemaker. This has, however, the disadvantage of introducing two complications, since the labourer had not performed any very laborious work for some years before his death, and his skeleton presented senile changes which were absent in the shoemaker.

These circumstances will not interfere materially with the points to which I wish to call attention. In supporting a heavy and moderately bulky load, such as this man was in the habit of carrying upon the shoulder and upper portion of the back of the thorax, the muscles which oppose the greatest resistance to the displacement of the scapula are the trapezius and the levator anguli scapulæ, the rhomboids performing a smaller share of the work. The strain thrown upon the deltoid, the lower portion of the subscapularis and teres major muscles is considerable; while that sustained by the supraspinatus is comparatively trivial. Consequently, we find in this scapula

that the supraspinous fossa is shallow, that there is not the slightest eversion of its upper or inner margins, that the vertebral margin, when regarded from the middle line of the body, presents a very perfect arc of a circle, beyond whose concavity the venter of the scapula is not seen to project; that the attachments of the deltoid and trapezius are well marked and extensive, rendering the posterior free margin of the spinous process very thick, and the outer border of the acromion longer than usual. The prolongation of the upper angle of the scapula in the direction of the traction exerted by the levator anguli scapulæ is very obvious, and the convexity of the vertebral margin in the situation of the insertion of the rhomboideus major, and the extensive surface of origin of the teres major and of the lowest intramuscular tendon of origin of the subscapularis are very well defined. To discuss this scapula more fully we ought to consider the many interesting characters which were presented by the upper extremity of the humerus and by the clavicle, but these I will leave for the present, as they would occupy too much space.

A consideration of these and other changes will show how useless it is to attempt to draw any definite conclusion from the formation of an average form of scapula or other bone from a number of such bones, collected together quite irrespective of the occupations or habits of the individuals from whom they were obtained. In such a study we cannot be too careful of the most minute detail, and the variations cannot be grouped under any single so-called index.

Other results of the same habitual strain exerted by those two muscles in the shoemaker are the extensive prominence of the insertion of the deltoid and the formation of a dense plate of fibro-cartilage in the tendon of the supraspinatus.

The infraspinatus and the two teres muscles exert a considerable amount of force in the production of the movement, though it is very much less than that exerted by the deltoid and supraspinatus. Therefore, we see that the markings on the scapula indicating the origins of the former muscles are proportionately less well marked than are those of the latter.

In the movement of the humerus upon the scapula the head of the former must articulate with an oblique oval area of the

glenoid cavity, whose direction runs from above downwards and forwards. There must, in consequence, exist a tendency for the shape of this cavity to change and to form an oval articular facet, its long axis having the direction I have indicated; also for the unused portion of the original articular surface to undergo changes consequent upon the absence of those movements, upon the presence of which it is dependent for the perpetuation of its normal form in the same manner that its original form was evolved by their acquisition. Also since the force exerted by the muscles upon the arm in the production of the movement, and the resistance offered to it, are greatest at its commencement, where the lower limit of the articular surface of the head of the humerus is in contact with the anterior and lower portion of the margin of the glenoid cavity, there must exist at that period a great tendency to the displacement of the head of the humerus downwards and forwards from the articular surface of the scapula. The presence of this tendency results in the development of a process of bone from the margin of the cavity, which runs outwards and forwards, and opposes this tendency to displacement. It is covered by articular cartilage. By this means the direction of the surface of this cavity becomes altered. It no longer looks directly outwards and slightly upwards, as in the normal subject or in the quadrumana, forming nearly a right angle with the plane of the body of the scapula, but it looks outwards, backwards, and upwards, as I have indicated in the diagram. I have already shown that, under the influence of strain which is exerted vertically downwards upon the shoulder-girdle by means of the humerus for considerable periods of time, as in carrying heavy loads in the hands, the surface of the glenoid cavity undergoes a change in its normal direction. The shoulder girdle is subjected habitually to such mechanical influences in occupations such as milkmen, a dissected specimen of which I have described in this *Journal*, p. 394, 1886—" Some Variations in the Human Skeleton."

It would therefore appear that a very considerable strain, exerted habitually in a downward direction by the humerus upon the shoulder-girdle for a long period of time, results in a gradual destruction of, or diminution in, the growth of the

anterior margin of the glenoid cavity, and possibly an excessive growth of its posterior margin, causing the surface of the glenoid cavity to look outwards and forwards, instead of outwards, as it does in the normal subject; also, that the momentary exercise of a sudden and considerable amount of strain, tending to displace the head of the humerus forwards and inwards from the scapular facet, results in changes in the form of that cavity the reverse of these just described, namely, an overgrowth of the anterior margin, and possibly a decrease in the extent of the growth of the posterior, causing the articular surface to look outwards and backwards. The character of the details of the changes depend largely in either case upon the age of the labourer when he commenced the particular form of occupation. This holds good for all labour and other pressure changes. This subject of the change in direction of the surface of the glenoid cavity in a horizontal plane is complicated by alterations in its direction in a vertical plane, so that in some cases the surface may look outwards, forwards, and upwards, and in others outwards, backwards, and downwards. In other cases there may be different combinations. In almost all the bodies which I have examined throughout, I have found myself able to explain the causation of the variation in the direction of the articular surface on simple mechanical principles, obtained from a study of the details of the particular work performed. I will not proceed further with the consideration of this subject in this paper, but will return to the consideration of the anatomy of the shoemaker.

The habitual performance of the movement determines a very distinct alteration in the shape of the articular surface of the upper extremity of the humerus, as in that of the glenoid cavity. The articular surface of the bone is rendered much more extensive than usual by the prolongation of the original facet in two directions. At the same time two portions of the original head have become functionless, since in the habitual movement they do not come into contact with the articular surface of the glenoid cavity. In consequence of the alteration in their function, the cartilage and subjacent bone undergo a series of changes which I have frequently described and illustrated. The portions of the head which undergo these changes

are the anterior and upper portion, and the lower and back part. The resulting articular facet corresponds in form and direction to that presented by the glenoid cavity, its long axis running from above downwards and forwards. The lower portion of the original head has been prolonged downwards and forwards, and ends in an abrupt margin, which corresponds in position and in causation to the growth of bone and cartilage upon the anterior margin of the glenoid cavity. If the humerus and scapula be placed in the position they occupy at the commencement of the movement of drawing the thread, the surface of the scapula is seen to be directly continuous by means of the marginal growth on the scapula and head of the humerus, with the surface of the neck of the humerus forming a complete arch. At the end of the movement it is observed that the upper and back part of the glenoid facet is in contact with the prolongation upwards, backwards, and outwards of the original articular surface of the head of the humerus.

In this shoemaker the long axis of the articular surface of the head of the humerus measured $3\frac{1}{16}$ inches, while its greatest breadth did not exceed $2\frac{3}{16}$ inches. The average diameter of the nearly circular articular surface in the normal vigorous adult measures about $2\frac{3}{4}$ inches.

The causation of the anatomical characters presented by the upper extremity of the shoemaker is very simple and obvious, and its consideration will not delay us long. The work done by the arms is very constant and considerable, and we therefore expect to find the bones larger than usual, the ligaments strong and thick, and the muscles well developed and in good condition.

The reader can readily understand the manner in which the several changes have been produced by assuming the attitude of the shoemaker, and by grasping cords which are connected to a central fixed point in the hand, the cord in the left hand being made to encircle the palm, and that in the right hand being attached to an awl or similar instrument held in it. Let him suddenly exert traction of a violent nature upon the strings in the direction and manner I have already described. He will then be able to determine accurately the tendencies which exist during the performance of the single movement to deviation from the normal typical anatomy, and from a careful consideration

of them he can arrive at the resulting changes which must develop in consequence of the very habitual existence of these powerful tendencies.

I will now enumerate the several tendencies to change which exist, and by referring to the anatomy of the shoemaker, the reader will be able to verify the existence of the tendencies by the presence of their actuality in that subject. In consequence of the great strain thrown upon the long tendon of the biceps as it passes over the projecting angle formed by the upper portion of the bicipital groove, a tendency exists to its acquiring an attachment to the floor or margins of that groove and to the dissociation of the portion of the long head which intervenes between that point and the glenoid cavity. The same great strain which is experienced by the tendon of insertion of this muscle while the fore-arm is pronated and flexed upon the humerus tends to produce an increase in the size and prominence of that portion of the tubercle into which the tendon is inserted, and in the area of the bursal cavity and articular surface of the tubercle in front of that insertion.

The same violent traction exerted by the biceps, especially at the commencement of the movement, assisted by that exerted by the supinator longus, tends to displace the head of the radius upwards and backwards from the position it occupies in this act, and to produce a proportionate increase in the thickness of the ligamentous structure which is chiefly engaged in opposing that displacement, namely, the interosseous membrane.

Since the opposing surfaces of radius and ulna are brought into comparatively forcible opposition only when the fore-arm occupies a position of pretty complete pronation, there exists a tendency for the portions of the articular surfaces so engaged to retain their normal articular covering, and to become more or less abruptly defined from the remainder of the articular surfaces, which, owing to their not performing the functions they are present to perform, undergo changes to adapt themselves to their altered circumstances.

The strain exerted upon the radius away from the elbow, and in the direction of the string, by the ligaments of the wrist and by the muscles which are attached to the radius, whether

directly, or indirectly by means of the interosseous membrane, tends to produce a displacement of the radius in that direction, a hypertrophy of the oblique radio-ulnar ligament, the external lateral ligament, and the portion of the anterior and posterior ligaments of the elbow-joint which oppose the displacement of the radius, and the development of a vacuum in the elbow-joint.

In consequence of the presence of this last tendency we would expect to find in one who had been engaged in this occupation for many years a nearly complete synovial fringe of a firmness and size proportionate to the duration and severity of the work performed, occupying the slight interval existing between the radial head of the humerus and the head of the radius where these surfaces are separated by the traction exerted upon the latter bone; also a very considerable hypertrophy of the intra-articular processes of synovial membrane, connective tissue and fat, which occupy the lateral notches in the articular surface of the great sigmoid cavity and the coronoid and olecranon depressions.

The habitual retention of the hand in a position of flexion, and of considerable adduction upon the pronated fore-arm, tends to produce an extension of the superior articular surface of the upper row of the carpus downwards upon the anterior surface of the scaphoid, semilunar, and cuneiform bones, and a consequent displacement of the attachment of the anterior radio-carpal ligaments downwards upon it; also a more abrupt definition of the posterior or ligamentous sections of the facets upon the upper surface of the scaphoid and semilunar bones. While the hand is in this position, the anterior surface of the styloid process of the ulna is retained in forcible contact with the inner surface of the cuneiform bone, and there exists in consequence of this a tendency to the formation of facets upon the opposing surfaces of bone and of a surrounding capsule, and so to the evolution of a complete arthrodial joint. It is very curious that we should find developed in man, as the result of the habitual performance of certain movements, a condition of the wrist-joint which closely resembles that which is normal in a large number of the quadrumana, in whom the factors determining its characters are equally obvious.

There exist other tendencies to change in the wrist-joint, on

account of the extreme adduction of the hand, namely, to the prolongation downwards of the inner articular surface of the cuneiform bone till it reaches the margin of the metacarpal facet, and even to the apposition of the cuneiform bone to the base of the fifth metacarpal; also, to an increase in the areas of the facets upon the upper angle of the cuneiform bone and the under surface of the semilunar bone. The vacuum which must exist between the upper row of the carpus and the lower surface of the radius, interarticular fibro-cartilage and styloid process, in consequence of the forcible separation of these surfaces, which is due to the great resistance offered by the leather to the passage of the threads through it, must tend to the development of interarticular, synovial, or fibrous fringes of varying density from the inner surface of the ligaments surrounding this articulation, as well as to an increase in the strength and thickness of those ligaments, and to a hypertrophy of those particular bands or layers of fibres which limit excessive adduction of the hand.

While the string is grasped in the left hand during the progress of the sudden and continuing strain exerted upon it, the thumb is retained in forcible apposition to the index finger by the powerful contraction of the flexor longus pollicis and of the several small adductor muscles of the thumb. The strain exerted upon the tendon of the long flexor of the thumb by its muscle brings the opposing articular surfaces of the bones of that digit into very forcible apposition. It tends to produce a forward displacement of the base of the first phalanx from the head of the first metacarpal bone, and, since that joint is partly flexed, to produce very considerable change in the form of the opposing surfaces of metacarpal bone and phalanx, in the form of the lateral ligaments and in the direction of their fibres, and to determine the formation of a synovial fringe in the angular interval which exists between the two bones posteriorly.

Since the carpo-metacarpal articulation is slightly flexed, the strain exerted by the flexor longus pollicis tends to the destruction of the anterior portions of the opposing articular surfaces, to the formation of an interval between their posterior portions, to the development of a synovial fringe or fibro-cartilage to occupy the interval, and to the hypertrophy of the posterior

carpo-metacarpal ligament. The same violent apposition of the opposing surfaces of the base of the over-extended second phalanx and the head of the first phalanx tends to produce very definite accommodation changes in their form, as well as an alteration in the length and strength of the ligaments which oppose over-extension.

There exists a tendency to the stretching of the vaginal sheath covering the anterior surface of the first phalanx, and to the displacement forwards of the tendon of the flexor longus pollicis from the anterior aspect of the upper portion of the bone. In this shoemaker the presence of this tendency has resulted in a very remarkable modification of the structure of the vaginal sheath. The very powerful oblique band of fibres represented in fig. 12, apparently originating in one of the limbs of the ligamentum cruciatum, which formed the structure whose function it was to oppose and limit the tendency to displacement of the tendon, was attached below to the anterior interphalangeal ligament, and indirectly through it to the anterior margin of the base of the terminal phalanx. Therefore, when the terminal phalanx was over-extended upon the proximal, the oblique band was rendered extremely tense.

The changes in the right thumb were very similar to those in the left, the differences which were present being dependent upon the fact that the awl was held in the right hand and the string alone in the left.

We seem to learn from the consideration of the anatomy of this workman, that we cannot observe and define too accurately the various modifications in form which the normal bones undergo under the influence of the groups of movements which compose some of the more routine forms of labour, because they represent the fixation and the subsequent exaggeration upon the bone of the results or the tendencies produced by one single movement, in the same manner that the total labour changes in the trunk indicate in a similar manner, first the fixation, and subsequently the exaggeration of the attitude which is assumed during a single performance of the movement or series of movements habitually performed in that particular labour.

Also, because the tendency to produce change in the form of

a bone may not be exerted sufficiently long or sufficiently often to produce the change in the parents, or it may, from some peculiarity in the form of the bone, be unable to result in it in either of the parents; yet the influence of that tendency, when it acts as a hereditary factor, may be sufficient to produce or determine the presence of the change in the offspring. That this must take place to a great extent in labourers is, I think, obvious from the consideration of preceding contributions to this *Journal*[1] and to the *Transactions of the Obstetrical Society*, 1887.[2]

EXPLANATION OF PLATE XIX.

Fig. 1 represents the anterior aspect of the atlas, with the prolongation upwards from its anterior arch, and the large quadrilateral mass of bone upon the upper surface of the left lateral mass.

Fig. 2 represents the foramen magnum and condyles of the occipital bone. B, the groove which received the sharp free upper margin of the articular facet upon the atlas; A, the transverse ligament which lay behind the upward prolongation of the odontoid process; C, the facet on the jugular process of the occipital bone, which articulated with the mass of bone projecting upwards from the lateral mass of the atlas.

Fig. 3 represents the axis and third cervical vertebra, the prolongation upwards of the odontoid process with its articular facet, the formation of a layer of bone connecting the arches of the axis and third cervical vertebra, and the seat of the ankylosed articulation of the articular processes.

Fig. 4 represents the upper surface of the right clavicle of the shoemaker. The upper margin of the acromial facet is indicated upon its outer extremity.

Fig. 5 represents the anterior surface of the same bone.

Fig. 6 represents a vertical transverse section through the right sterno-clavicular articulation of an old sailor.

Fig. 7 represents the posterior aspect of the right scapula of the shoemaker, and fig. 8 its vertebral margin. The dotted line in fig. 8 indicates the outline of that portion of the venter of the scapula which corresponds to the floor of the supraspinous fossa.

Figs. 9 and 10 represent respectively the posterior surface and the inner margin of a scapula of a labourer who carried habitually loads on his right shoulder.

[1] " Can the Existence of a Tendency to Change in the Form of the Skeleton of the Parent result in the Actuality of that Change in the Offspring?" 1888.
[2] " What are the Chief Factors that Determine the Variations which exist in the Form of the Male and Female Pelvis?"

I have represented in fig. 11 the posterior surface of the upper extremity of the left humerus.   A points to a portion of the original head which had become functionless; B to the acquired articular surface; and C to an atrophic patch, all of which have been described in this paper.

Fig. 12 represents the trapezium, metacarpal bone, and phalanges of the thumb of the shoemaker.

ON SOME POINTS IN THE ANATOMY OF A MEGAPTERA LONGIMANA. By JOHN STRUTHERS, M.D., *Professor of Anatomy in the University of Aberdeen.*

PART III.—*continued.*

THE VERTEBRAL COLUMN—*continued.*

NEURAL ARCH AND CANAL.

11. THE LAMINA.—The length of the lamina is remarkable compared with that of B. musculus, but owing to its obliquity (upwards and backwards) and greater thickness the canal is not higher than in B. musculus. The obliquity of the lamina is very slight on the 1st dorsal, increases on the 2nd, 3rd, and 4th, is very marked on the 5th and back to the 1st lumbar; after this it diminishes rapidly along the posterior half of the lumbar region, so that at the 9th or 10th lumbar the lamina is not longer than at the same place in B. musculus. At the last dorsal the length of the lamina proper is about 2 inches, breadth 4, thickness 1½. At the last lumbar the length is 1 inch.

In *B. musculus* the first three dorsal laminæ are directed a little forwards; obliquity backwards begins on the 5th. The much less length of the laminæ, compared with Megaptera, is recognised on the 7th and 8th, as soon as the articular processes assume the definite quadrate form. On the last dorsal, the length is 1 inch, breadth 5½, thickness about 1 inch. The shortness of the lamina and the less width apart of the articular processes, compared with Megaptera, are co-relations.

12. THE PEDICLE.—The upper limit of the pedicle is defined by a smooth elevation crossing it obliquely from the margin of the articular process to a tubercle on the posterior margin of the pedicle. This tubercle is present as a flattened pointed projection (1 inch in height at the base, and about ¼ inch in length) from the posterior margin of the pedicle, from the 8th dorsal back to the 4th or 5th lumbar. On the dorsal vertebræ in front of the 8th there is, however, serial with it, a rough elevation a little in front of the border of the pedicle. The tubercle appears to be in relation with the anterior inferior corner of the articular process of the vertebra behind it, as if a ligament passed between them, the tubercle a little lower than the process. It disappears in the lumbar region just where the articular processes cease to have an anterior inferior corner.

In *B. musculus* there is no projecting tubercle, but along the dorsal region there is a low rough elevation a little in front of the posterior border of the pedicle, at its base and about an inch below the level of the anterior inferior corner of the quadrate articular process behind it.

The great *thickness* of the pedicle of several of the dorsal vertebræ anterior to the 8th, is owing to its being also the root of the transverse process. Behind this the thickness does not vary much, diminishing slowly backwards; at the 9th dorsal, 1⅜ inches; at the 13th dorsal, 1½; at the 8th lumbar, 1 inch; at the 4th caudal it has increased to 1⅙, and behind this it increases a little. The *breadth* increases backwards as the thickness diminishes; at the 8th dorsal, 3¼ inches; 10th dorsal, 3½; 1st lumbar, 4; 2nd and 3rd caudal, 4⅛; but after the 3rd caudal it decreases a little.

In *B. musculus* the *thickness* of the pedicle from the 9th dorsal to the 3rd caudal does not exceed ⅝ inch; from the 13th dorsal to the 14th lumbar it is only ½ inch. The *breadth* along the lumbar region and posterior half of the dorsal is 4¼ to 4½ inches.

The *posterior border* of the pedicle is concave, the concavity continuous with that of the lamina, interrupted only where the tubercle above referred to exists. The concavity appears to increase in depth as we go back, owing to the greater projection of the posterior articular process; but it is less in the caudal region, in which, after the 2nd caudal, the pedicle, lamina, and spine all go upwards and backwards with very little obliquity. The *anterior border* rises from the fore part of the body close to the epiphysis, and curves very obliquely upwards and forwards, owing to the form of the articular process. The anterior inferior angle of the process is 3 inches above the body, giving a high intervertebral foramen compared with B. musculus.

In *B. musculus* the *posterior border* of the pedicle is concave along the whole column. The *anterior border* in the dorsal region curves abruptly forwards to join the lower border of the quadrate articular process, forming nearly a right angle and giving a low intervertebral foramen. The lower border of the process, forming the upper boundary of the foramen, is about 2 inches above the level of the body.

The pedicle is set upon the body quite close to the anterior epiphysis all along the column, but at some distance from the posterior epiphysis,—at the 8th dorsal, 1 inch from it; at the 10th lumbar, 1¾ inch. Hence the intervertebral foramen belongs more to the anterior than to the posterior vertebra, although the articular process makes the latter encircle the foramen most.

In *B. musculus* the pedicle does not arise so near the front of the body as in Megaptera. At the 8th dorsal it is ¾ inch from the anterior epiphysis, 1½ from the posterior epiphysis; at 10th lumbar, the same; at 15th lumbar, ½ inch from the anterior epiphysis, 1½ from the posterior, but curves very rapidly back at its anterior origin.

Neuro-Central Suture.—Traces of the closed neuro-central suture are present from the 9th lumbar forwards to the 8th dorsal. They are seen and felt as continuous raised lines, along the outside, at about an inch below where the pedicle appears to spring from the body. In front of the pedicle the line would cut off but a small part of the body as belonging to the neural arch. The line is still above the transverse process on the 8th

dorsal, and irregular. No definite trace of it can be recognised on the 7th dorsal.

No certain trace of this suture can be seen in this B. musculus.

13. NEURAL CANAL.—In *height* the canal shows very little difference along the dorsal region, from 3⅝ inches at the first to the same at the last dorsal. It is 3⅞ at the 8th, 9th, and 10th, the highest part of the whole canal. Along the lumbar region it falls from 3½ to 3; along the caudal region from 3 at the 1st to 1¾ at the 5th, and to ¾ inch at the 10th caudal. The *breadth* diminishes backwards with slight exception, as seen in Table II. At the 10th dorsal, the breadth is but half what it is at the 1st (7⅞) inches. From the 10th dorsal (3½) to the 7th lumbar (3⅝) there is very little change.

The floor of the canal presents the longitudinal elevation, with the concavity and foramina on each side of it, noted with the bodies. In the dorsal region the general concavity of the side, of the Gothic arch form, is interrupted by an inward bulge opposite where the lamina and pedicle meet. In the lumbar region this minor convexity is higher up. At the 4th caudal the canal assumes an almost square form, changing to a rounded or oval form at the 7th and in the three remaining vertebræ which possess a completed neural arch.

In *B. musculus* the *height* of the canal increases from the 1st dorsal (3 inches) to the 11th (4⅜), and then diminishes (at last dorsal, 3⅞; at 1st caudal, 3½). The *breadth* diminishes backwards along the dorsal region (1st dorsal, 7¹⁄₁₆; last dorsal, 3½); increases a very little in the anterior two-thirds of the lumbar region, and again diminishes backwards. Except on the first three dorsal the height of the canal is greater all along than in Megaptera. The breadth is about the same in both from the 3rd dorsal to the 8th lumbar, behind which it is greater in B. musculus than in Megaptera.

ARTICULAR PROCESSES.

(*Dorsal, Lumbar, and Caudal.*)

14. GREAT ANTERIOR ARTICULAR PROCESSES.—The specially developed articular surfaces of the five or six anterior dorsal vertebræ are seen to be very different in Megaptera and B. musculus when the two series are laid together. In Megaptera

the first is nearly semicircular (2½ by 1¼ inch) and very shallow; ½ inch more in its long direction than that of the 7th cervical and not so flat, and has, like the 7th cervical, a deep pit behind. The 2nd, 3rd, and 4th are increasingly narrower and much bent (the 3rd, length, outwards and forwards, 3 inches, breadth, antero-posteriorly, under 1 inch) and much raised on their oblique outer three-fourths, like the side of a trough. The 5th is a deep ovoid fossa (2 inches by 1½) with a deep non-articular pit (1 inch long) behind it. The 6th (2¼ by 1½) is a shallow mostly vertical surface with a smaller pit behind it. The 7th becomes suddenly lost as an articular cavity, presenting only a smooth apparently non-cartilaginous area bounded by faint ridges.

In *B. musculus*, the 1st is a semi-elliptical surface (2¾ by under 1 inch) and more raised externally than in Megaptera; the 2nd and 3rd are quite shallow semi-lunes; the 5th, a shallow pointed ovoid (2½ inches by 1 inch), facing obliquely inward, with a pit behind; the 6th suddenly shows the first internal process, and, in front of this, a flat vertical area without sub-cartilaginous appearance.

Surveying the series of the ordinary great anterior articular processes, they are strikingly different in Megaptera and B. musculus, especially in the dorsal region; rhomboid and directed upwards and forwards in Megaptera, square-shaped in B. musculus. In Megaptera, back to the 6th lumbar, the concave anterior border of the pedicle rises obliquely to the articular process, meeting it at a rounded obtuse angle, and the anterior border of the process is directed upwards and forwards. The posterior border of the process is oblique, in the same direction. The upper border is a little convex, about ½ inch thick and unfinished. The unfinished edge turns down for ½ inch to 1 inch round the anterior corner, not at all on the posterior corner, so that any further ossification would increase the obliquity of the processes. On the last four lumbar, the angle between the anterior border of the pedicle and the process becomes rounded, and, on and after the 1st caudal, is lost, so that the pedicle and the process now form one interrupted concave anterior border. This concave border becomes less and less oblique, is vertical from the 5th to the 7th caudal, behind which the articular processes are merely low convex ridges. On the last

lumbar and two first caudal, the top of the articular process falls nearly 1 inch compared with those in front; behind this they again rise in height. After the next last lumbar, the posterior border of the process becomes concave backwards, and this with the diminishing obliquity of the anterior border gives the processes, after the 2nd caudal, a straight-up direction, the process increasing somewhat in breadth upwards.

In *thickness* the processes undergo sudden increase at the unfinished top, from $\frac{1}{2}$ inch on the last lumbar to 1 inch on the 1st caudal, and to $1\frac{1}{2}$ inch on the 5th caudal at its middle; after which they diminish, but are still 1 inch thick on the 10th, the last vertebra with a complete neural arch. On the next four vertebræ (11th to 14th) the low ridges, perforated by the passage above noted, represent pedicle and articular processes combined.

The greater *width-apart* of the articular processes in Megaptera, compared with B. musculus, is at once seen in surveying the series from the atlantal or the caudal end. Taking the measurement at the fore part of the processes, inner edge, the distance falls from the 1st to the last dorsal from $11\frac{1}{4}$ inches to $4\frac{1}{4}$; at the 5th and 6th lumbar it is 4 inches; at 9th lumbar, $3\frac{1}{4}$; at 1st caudal, $2\frac{1}{2}$; at 8th caudal, $1\frac{3}{4}$; at the 10th caudal, $1\frac{1}{8}$. The measurements are given in full in Table II. The measurements of a process at the posterior dorsal or anterior lumbar region are—height, $3\frac{3}{4}$ inches; length, 3; thickness, at the unfinished top, $\frac{5}{8}$ inch, at the middle, $\frac{7}{8}$ to 1 inch. The anterior border, and anterior part of the lower border, are much thinner, giving the process a wedge shape.

Great Anterior Articular Processes in B. musculus.

In *B. musculus* the decidedly quadrate form is seen from the 7th dorsal to the 1st lumbar. In front of the 7th dorsal, the upper anterior angle rapidly disappears, reducing the process to a narrow triangular projection, which, on the three first dorsal, is some distance external to the articular surface. The quadrate form, as compared with the form in Megaptera, is obtained by the development of the anterior-inferior and posterior-superior corners. The inferior-anterior forms almost a right angle, but a little rounded off. The measurements at the 14th dorsal are—height, $4\frac{1}{4}$ inches; length, $4\frac{1}{2}$; thickness at the top, $\frac{3}{8}$, at the middle, the same. The thinness of the processes is remarkable compared with those of Megaptera. The

development of the upper posterior corner partly carries the process backwards to opposite the fore part of the spinous process, but in Megaptera it is mainly the greater length of the lamina which makes the articular process seem so far in front of the spine. The development of the anterior-inferior corner in B. musculus, bringing the lower border so low as almost to form a right angle with the pedicle, renders the intervertebral notch very low, the anterior part scarcely 2 inches above the level of the body, while in Megaptera the same measurement is about 3 inches.

After the 1st lumbar, the processes become less quadrate, and more like those of Megaptera, the lower anterior corner rounded off, and, after the 5th lumbar, reduced to a mere convexity. After the 14th lumbar, the pedicle and the process form an uninterrupted concave border, going up to the blunt point of a triangular process. The 6th, 7th, and 8th caudal are directed up, with a little concavity on both borders. From the 9th backwards, the short bluntly triangular processes have a direction rather backwards. But all along the lumbar and anterior caudal regions, the posterior angle remains nearly a right angle, and the upper border has very little convexity. In the caudal region, the processes become much thicker, increasing to the 9th, where the thickness is $1\frac{1}{2}$ inches.

In *width-apart*, the distance falls, from the 1st to the last dorsal, from 10 inches to $2\frac{7}{8}$. At the 10th lumbar it has increased to $3\frac{1}{4}$, and from this vertebra, backwards, the width-apart of the articular processes is greater in B. musculus than in Megaptera. (Compare Tables II. and III.)

15. INTERNAL OR LESSER ANTERIOR ARTICULAR PROCESSES. —These processes, so well developed in B. musculus, are present here only on the last lumbar and three first caudal vertebræ, and only to a rudimentary extent. On the 2nd caudal, where they are best marked, they project about $\frac{1}{8}$ inch, and have a vertical base of about $1\frac{1}{2}$ inch, the triangular fossa between them $\frac{1}{4}$ inch deep and $\frac{3}{4}$ inch wide in front. On the 3rd caudal they are only low ridges, on the 4th all trace of them is gone, giving a wide uninterrupted space between the great articular processes. On the 1st caudal they are nearly as well developed as on the 2nd, with wider interval between them; on the last lumbar they are less marked, and faint traces of them exist along the trunk vertebræ.

To interpret these processes, begin at the 6th dorsal vertebra, the most posterior of those presenting an articular socket. The outer and inner edges of that socket are represented on the vertebræ behind by two lines, one, now the sharp one (sharp until the internal articular processes appear at the 10th lumbar),

running to the border of the spinous process, the other leaving that line at about opposite the middle of the great articular process, and going vertically down; and there is a roughness where the two lines separate. Arrived at the 9th lumbar, the vertical line is more distinct, and on the four vertebræ behind rises into the internal articular process above described. Between these two lines, as we go back along the dorsal and lumbar regions, the bone is smooth, facet-like, but not as if it had supported cartilage. The facet, scarcely excavated, is square-shaped along the dorsal region, is about 2 inches vertically by 1½ inch, and along the lumbar region becomes gradually triangular and smaller. On the 10th lumbar it is in front of the lesser process and mostly higher up. Where these lesser processes are present, though in a rudimentary state, the posterior articular processes are undergoing modification, and the great anterior processes on the 10th lumbar and first two caudal are lower than on the vertebræ before and behind them.

The mode of breaking up of the anterior border of the spinous process is characteristic in Megaptera. The bifurcation of the very sharp ridge of the border takes place high up. It is seen to take place a long way behind the articular processes until we go back to the 8th lumbar, when that relation begins to be reversed. But this is mainly owing to the length and obliquity of the lamina, which decrease backwards in the lumbar region. The actual early bifurcation is seen by the height of the wide triangular concave area from it down to the level of the roof of the neural canal, 2½ to 3 inches, while in B. musculus it is scarcely half that height, and is greatly narrower from the presence of the lower articular processes.

Internal Anterior Articular Processes in B. musculus.

In B. musculus these processes are present from the 6th dorsal to the 14th lumbar, with traces farther back. The 5th dorsal is the most posterior of the vertebræ presenting an articular socket. Going backwards, it is seen that the internal, or minor, articular process is serial with the inner edge of the socket of the 5th dorsal. Increasing rapidly, it is fully developed from the 10th dorsal to the 10th or 11th lumbar. In its full size it is a triangular flattened process, projecting ½ to ⅝ inch with a base 1½ inch in height, pointed and sharp-edged, and about ¼ inch thick at the middle. The median fossa between the minor processes contracts very much as we go back

(at the 7th, depth 2¼ inches, width in front 3 inches; at 10th dorsal, depth 1 inch, width in front 1½) to the 15th dorsal (depth ¾, width in front ⅜); after the 3rd lumbar it begins to widen a little (at the 11th, depth ⅞, width 1 inch). All along, the fossa between the internal and the great process, about ½ inch deep, will scarcely receive the little finger. The sharp line from the low bifurcation of the anterior border of the spinous process runs to this internal process, from the 6th dorsal backwards.

16. POSTERIOR ARTICULAR PROCESSES.—After the 5th dorsal there is no posterior articular surface bearing the appearance of having supported cartilage. The process, better developed in the other two finners, is represented by the backward projection where the ridges into which the posterior border of the spine bifurcates join the diverging laminæ, internal to the anterior and upper part of the great anterior processes.

The sloping triangular space included between the bifurcation of the posterior border of the spine and the neural arch, begins higher and is much broader than in the other two finners. In regard to this character Megaptera and B. musculus may be compared at the 4th lumbar, at which the angle formed by the spine is the same in both, and where the neural canal is the same in width (3⅝ inches) and only ¼ inch lower in Megaptera (3¼) than in B. musculus. In Megaptera the bifurcation begins 6½ inches above the body and 1½ behind the vertical plane of the posterior end of the body; in B. musculus, 5½ above the body and ½ inch behind the same vertical plane. The triangular space in Megaptera is over 1½ inch in breadth at the middle and shallow; in B. musculus about 1 inch and deeper. The contrast increases as we go back, while the triangular space becomes narrower in both. In Megaptera, at the same time, the posterior articular " process " becomes more projecting, back to the 9th lumbar.

On the last lumbar and two first caudal there is a decided triangular mesial projection above the beginning of the bifurcation. It is at this limited region where the minor anterior articular processes exist, and in the fossa between the latter is a low median ridge, not present anywhere else in Megaptera, or at any part in the other two finners. On the last lumbar and three first caudal, where the triangular space between the posterior articular processes runs into the roof of the neural canal,

there is a thick prominent mesial ridge about the size of a little finger, but prismatic. It is less marked on the 4th and 5th caudal. Forwards, it is only slightly present in several of the posterior lumbar vertebræ, and re-appears on the posterior half of the dorsal region as a low convexity.

In *B. musculus* this mesial ridge is very faintly and variably present on some of the lumbar vertebræ.

The bifurcation of the posterior border of the spinous process is quite peculiar on 3rd, 4th, and 5th dorsal. It begins near the top of the spine and the included space, half-way down, is nearly 1 inch broad, grooved and with a low median ridge. The difference behind the 5th dorsal is owing to the development of this low median ridge as the posterior border of the process, and to the partial filling up of the groove on each side of it.

In *B. musculus*, the posterior articular processes, back to the 10th dorsal, project far enough to be opposite about the upper and anterior third of the minor anterior processes; more forwards, less as we go back. In the lumbar region the distance between them, antero-posteriorly, increases to about 1 inch. If the posterior processes move straight back, in extension, to that extent, they must go between the minor anterior processes, but they will not touch, as the distance between the latter is considerably greater than that between the two posterior articular processes. The above mentioned character of the 3rd, 4th, and 5th dorsal spines in Megaptera is not seen in B. musculus, in which the posterior edges of all the spines are thin and projecting.

17. HOMOLOGY AND ADAPTATION OF THE ARTICULAR PROCESSES.—The internal anterior articular processes may be looked on as the true zygomal processes, the great anterior processes rather as metapophyses. Behind the articulation between the 5th and 6th dorsal there is no appearance of the part having been covered by cartilage, but dissection alone can determine that. After that articulation the processes cease to be in contact, the interval increasing from $\frac{1}{2}$ inch rapidly to $\frac{3}{4}$ inch, laterally, as we go back. With this distance between them, laterally, the anterior and posterior processes could not come in contact without more rotation on the axis of the bodies than the intervertebral discs are likely to allow. At the posterior lumbar and the caudal regions they could not even approach each other antero-posteriorly except during severe extension.

In *B. musculus*, as the posterior articular processes would pass, in extension, internal to the lesser anterior processes, the latter maintain their usual position as the true anterior articular processes. Whether they are serial with the outer or inner margin of the articular surfaces on the anterior dorsal vertebræ does not affect their homology, as they are to be regarded as these processes somewhat rotated, so that the sides of the zygantrum are more vertical.

TRANSVERSE PROCESSES.

18. GENERAL REMARKS ON THE TRANSVERSE PROCESSES IN CETACEA.—The dorsal transverse processes vary much in the Cetacea, in their place of origin; in direction, antero-posteriorly or vertically; in form; in length, breadth, and thickness, and in the form of their costal facets. Dorso-lumbar transverse processes have generally a forward direction, except some of the posterior dorsal which have a backward direction. This may be said of Mammalia generally, but the greater length of the posterior dorsal transverse processes in Cetacea renders it more evident in them. This is very clearly seen in the toothed Cetacea, *e.g.*, Globicephalus and Phocena communis. The greatly forward direction of the anterior dorsal transverse processes enables the head of the doubly-attached rib to reach the body of the vertebra in front. The more posterior of the ribs have only the costo-transverse articulation, are a-sternal, and have a greater slope downwards and backwards than the anterior, and the transverse processes which support these ribs are directed backwards. The lumbar processes, generally after the first, again assume the forward direction. In the Balænopteræ, the neck and head of the anterior ribs are represented by a ligament, and the very greatly forward slope of the anterior dorsal transverse processes builds up posteriorly the great lateral pyramid formed by them and the cervical transverse processes. There is, in them, the same backward direction of the posterior dorsal transverse processes where the ribs become smaller; the lumbar, again, after the first, assuming the forward direction.

A typical dorsal transverse process may be divided into two stages, which may be termed the neck and the wing, seen best in Balænoptera musculus. Both borders are at first concave where they join the body. The stages are strongly-marked on the anterior border, where an angle is formed about the middle

by the rapid falling away of the border inwardly on the neck stage. This angle may be developed into a special projection. The typical anterior border is thus sigmoid. The posterior border, at rather internal to the middle, presents a low projection, sometimes well marked, giving a gently undulating form to the border. These anterior and posterior intertransverse projections mark off the neck stage, and are apparently the points of attachment of ligaments or tendons, or the inward part of such attachments to the more or less expanded wing stage. The curvatures on the upper and under surfaces of the transverse processes depend on the amount of upturning of the processes, and on the amount of thickening at the outer ends to support the articular surfaces for the ribs. Typical lumbar transverse processes have the same form except in regard to what depends on the absence of costal facets and of upturning.

19. The Transverse Processes of Megaptera—Dorsal Region.—The most striking characters of the dorsal transverse processes in Megaptera are their up-curving outwardly, and their thickness combined with narrowness.

Place of Origin.—The four first spring from the pedicle, the 5th, 6th, and 7th are transition in this respect, the transverse process gradually springing lower from the common stalk. The 8th may be considered as quite distinct from the pedicle. Behind this, there is more and more separation of the transverse processes from the pedicles. That this is mainly due to the processes and pedicles becoming thinner, not to the processes coming down on the bodies, is seen on a side view. The roots of the transverse processes are then seen, from the 4th to the 13th, to be on a curved line, convexity upwards. This is in harmony with the upturning of the processes as an adaptation to the ribs. The root of the 14th is nearly on a level with those of the lumbar, being nearly as low as the middle of the body.

The transverse processes, whether united with or separate from the pedicles, spring from nearer the anterior than the posterior end of the bodies, from the 1st to the 12th, on which latter the distances are about equal; but on the 13th and 14th, and on the 1st lumbar, they spring nearer the posterior than the anterior end. This change does not apply to the pedicles, all of which spring nearer the front than the back of the bodies.

Direction of the Dorsal Transverse Processes.—The three first have, like the cervical, a downward direction, and are concave below. Above, the two first have little if any concavity. The 1st is not only directed forwards but is bent with the concavity forwards. The 3rd is a little concave above. The 4th is directed a little downwards, and is sigmoid but mostly concave below; above, it is very concave and looks upturned, but is not so high externally as internally. The upturning is very marked from the 5th to the 12th, is but little on the 13th, and the 14th is nearly horizontal. The 5th, as seen from below, ascends 2 inches. Above, it presents a concavity 1½ inch deep, though the outer end is not much higher than the inner, from the connection of the latter with the articular process. The 10th rises 5 inches, measured below; 3½ measured above, the concavity 1⅓ deep. A line from tip to tip of the transverse processes of the 10th intersects the articular process, cutting off its lower fourth, and passes 3 inches above the level of the body of the vertebra.

The forward direction of the processes is well-marked on the four or five first, and lessens to the 8th, on which the anterior edge of the transverse process is just on a line with the front of the body. The distances to which the transverse process reaches beyond the front of the body of the vertebra are—the 1st, 2 inches; the 3rd, 3 inches (angle 22°); the 5th, 2¾ inches; the 7th, ¾ inch. The backward direction of the processes begins with the 9th, increases to the 12th or 13th (angle about 15°), and diminishes on the 14th. The hinder edge of the process begins to take the backward direction on the 7th. The most posterior part on the 9th is flush with the back of the body. The distances to which the processes pass behind the plane of the back of the body of their vertebra are⸺the 11th, 2 inches; the 13th, 2 inches; the 14th, 1¼ inch.

In *form*, the dorsal transverse processes pass through a transition from the form of the cervical to that of the lumbar,—the anterior, flattened with the surfaces before and behind, prismatic in transition, and, towards the lumbar region, flattened with the surfaces above and below. The great convexity which the 2nd has gained on its posterior surface becomes developed into and remains as the posterior border as we go backwards. The

superior border remains as the anterior border. The inferior border is gradually carried backwards to below the flattening process, and forms the lower edge of the prism; is thick internally, is continued externally in front of the fossa, as the lower edge of the prism, and disappears as we go back, except as the anterior boundary of the costal fossa. The transition is rapid on the 4th; the 14th is about as flat below as it is above, like a lumbar process, though not so thin.

The borders on the first five are, the anterior, like the posterior cervical, concave; the posterior, convex. The 6th is transition in these respects. On the 7th, and backwards, these curvatures appear reversed, but anterior and posterior intertransverse projections make their appearance on the 6th, and continue with variable prominence after the 6th, so that the true form of the hinder edge is that of a low prominence with gentle concavity on either side, and that of the anterior edge sigmoid, the concavity on the neck stage.

On their upper surface the transverse processes are, after the first four, concave in their whole length; from the 5th to the 12th very much so, owing to the great rise of these processes outwardly. On the 13th, the concavity is much less; the 14th shows a shallow sigmoid curvature, the concavity on the outer half.

Length, Breadth, and Thickness of the Dorsal Transverse Processes.—In *length* they increase gradually from the 1st to the 14th, and begin to diminish from the 4th lumbar backwards. In *breadth* they increase from the 1st to the 10th, and diminish a little on the 13th and 14th. The wing stage is marked off by the low intertransverse projections and by the greater breadth, but the difference in breadth is not very great. On the 7th the neck is 3 inches in breadth, the wing 4½. The spaces between the processes, in the articulated skeleton, are about as wide as the processes themselves, a good deal wider internally, scarcely so wide externally. In *thickness*, taken at the middle, the 3rd, 4th, and 5th processes are the greatest (2½ inches), after which the thickness diminishes, and rapidly so on the 13th and 14th.

20. COSTAL FOSSÆ ON THE TRANSVERSE PROCESSES.—The fossæ on the transverse processes for articulation with the ribs

are best marked on the 10th and 11th. They are shallow cavities, in form the lower half of an ovoid, the point directed inwards and downwards. The 10th measures 4 inches in the inward and downward direction, $3\frac{1}{4}$ inches antero-posteriorly; the greatest depth is $\frac{5}{8}$ inch. On the three first there is no pit, only the blunt convex unfinished end of the processes. The thick blunt end of the 3rd is more sloping below than above, but there is no hollow or costal mark. The fossæ begin on the 4th, where it is well marked, increase in size and in depth backwards to the 10th, and diminish in size, but have sharper edges, on the 11th and 12th. On the 13th there is a very shallow triangular facet, 2 inches wide. The 14th process presents only an elliptical outer end, twice the thickness of the end of the 1st lumbar, the lower and back part of which shows a slight costal bevelling.

The fossæ reach to the outer end of the process and occupy the posterior of the two under surfaces, as if formed by a bifurcation of the inferior border of the process, but the anterior edge of the fossa is the prominent one. The surface in front of the fossa, at first narrow, becomes gradually broader as we go back, attaining on the 12th the same breadth as the fossa. The fossæ look mainly downwards, to a less extent outwards and backwards. Viewed from the side the ends of the processes are seen to form crescents over the fossæ, directed very obliquely forwards and downwards, with a short continuation forwards from the 7th to the 12th. These margins and the fossæ would probably be more sharply marked in the completely ossified state. Here, taking the 7th, the thickness of the unfinished edge, opposite the middle of the fossa, is 1 inch.

21. LUMBO-CAUDAL TRANSVERSE PROCESSES.—In *place of origin* all the lumbo-caudal transverse processes, after the first, are on a line with about the middle of the bodies. After the 2nd lumbar they spring from rather nearer the front than the back of the bodies; in the caudal region it is rather the opposite, this arising from the increased depth in the caudal region of the anterior concavity of the neck of the process.

In *direction*, the lumbar transverse processes have a more or less forward tendency after the 1st, which is directed slightly backwards (angle 5°). The 2nd is directed a little forwards, the

3rd and 4th more so, the 5th to the 8th decidedly forwards (angle at the 7th, about 22°), the 9th a little, the 10th very little. The direction of the caudal transverse processes is variable, depending on the non-development of the anterior or posterior angles of the wing, external to the intertransverse projections. The direction of the 1st is straight out; that of the 2nd and 3rd backwards, owing to the failure of the anterior angle of the wing; that of the 4th a little forwards, that of the 5th and 6th very much forwards, owing to the want of the posterior angle and of almost the whole of the wing, and to the great depth of the anterior concavity of the neck. The 7th and 8th are mere lateral ridges. The change of the posterior border to the backward direction begins on the 9th lumbar and continues to the 4th caudal.

In *length* the processes continue the same as the last dorsal to the 3rd or 4th lumbar, after which they diminish; after the 6th lumbar rapidly, after the 3rd caudal very rapidly. On the 6th caudal they are very short, on the 7th and 8th they are represented by a mere tubercular trace. In *breadth* they increase a little by expansion of the outer half, to the 8th lumbar, after which the breadth diminishes as we go back. In *thickness*, taken at the middle, they are pretty uniform. On an average the thickness is about 1 inch, about half that of the dorsal transverse processes.

In *form* the processes show more than in the dorsal region the distinction between neck and wing, as they broaden outwardly and shorten, on the posterior lumbar and anterior caudal region. On the anterior border, the intertransverse projection becomes more marked on and after the 9th lumbar, from the falling away of the wing external to it. This becomes more marked on and after the 1st caudal, giving the anterior border a backward direction external to the projection. Thus the typical sigmoid form of the border becomes more marked backwards. From the 9th lumbar backwards, the concavity is more striking, partly from being deeper, partly from now occupying a greater proportion of the length of the now shortening processes. From the 3rd to the 6th caudal, the concavity becomes increas-
ep and narrow, and on the 5th is manifestly the opening
a vertical passage seen on the vertebrae behind it. On

the posterior border, the intertransverse projection is seen in various degrees, giving the wavy outline.

The ends are all convex and incompletely ossified, except the 5th and 6th caudal, which are sharply finished. The unfinished state being only at the ends seems to indicate that further ossification would have added to the length but scarcely to the breadth of the processes. On the whole, these processes do not expand much, although on the last five lumbar it is noticeable enough. The breadths of the narrowest and broadest parts of the process, respectively, are—of the 1st lumbar, 3¼ and 4 inches; of the 8th, which has the greatest expansion, 3½ and 5½; of the 10th, 3⅝ and 4⅝.

Comparing the breadth of the lumbar processes at their outer half with that of the spaces between them, the first two spaces are rather less than the processes; the five next about equal. From the 8th vertebra backwards, the spaces become wider and wider compared with the processes. Between the first five caudal the spaces are two to three times as wide as the processes. This depends not only on the processes becoming narrower, but on the increased distance in the caudal region between the bodies of the vertebræ.

22. GENERAL SURVEY OF THE TRANSVERSE PROCESSES IN MEGAPTERA.—Viewed from the caudal end and from above, the extreme outline of the processes, from the last costal vertebra backwards, has the figure of the hinder half of an ellipse, the convex edges tapering very rapidly on the 4th, 5th, and 6th caudal, the latter being the first which shows a prominent transverse process. This view of Megaptera is remarkable for the absence of transverse processes on the fifteen posterior caudal vertebræ, a space of about 7½ feet, giving the caudal vertebræ a clipped appearance. Forwards, what strikes the eye is the upturning of the dorsal transverse processes, becoming very marked on the 12th. At the same time the outline figure narrows forwards to form the fore part of the ellipse, but the tilting up of the dorsal processes breaks the outline. Viewed from the atlantal end, the upturning of the dorsal processes is still more apparent, rising like the ribs of a ship. The outline along the dorsal processes shows contraction forwards, but not much convexity. To the eye the 14th dorsal seems the widest,

with diminution immediately behind and before. The eye does not detect that the first three lumbar are equally wide, nor would the eye detect so great a diminution as 6 inches from the 14th to the 8th dorsal.

23. Transverse Processes in B. musculus compared with those of Megaptera.

The transverse processes differ much from those of Megaptera, in expansion of their outer two-thirds, in being much thinner, and in being very little turned upwards in the dorsal region.

24. Dorsal Region.—*Origin.*—The root common to the pedicle and the transverse process on the first four is more oblique than in Megaptera. On the 7th, the pedicle and the process are as distinct as on the 8th of Megaptera. Behind this, as seen from above, the processes spring from lower on the bodies than in Megaptera. This is owing to their thinness. Seen from below, they do not spring so high from the bodies as in Megaptera, but from the 4th to the 13th their line of origin is slightly convex upwards. At the 15th, the process is thin enough to have fallen quite to the level of the middle of the body.

Direction.—The first is straight. The three first are decidedly concave above. Viewed from above, the processes appear to the eye to rise outwardly from the 5th to the 12th, but it is from the 7th to the 13th that the outer end of the process is really higher than the inner part, the 13th very little. The rise above the costal fossa renders the outer half concave. From the 6th, diminishing backwards, the inner half of the process is rather convex. A line from tip to tip of the transverse process of the 10th shows a rise of $1\frac{1}{2}$ inch from the neck to the tip of the process. The line is on a level with the body' at its hinder edge and $1\frac{1}{2}$ inch below the articular process. The concavity is about $\frac{1}{4}$ inch deep. On the 7th it is twice that, the depth increasing forwards owing to the inward rise of the process to the articular process. Viewed from below, the processes rise a little outwardly from the 7th to the 13th. The *forward direction* of the processes is greater than in Megaptera. The distances to which the processes pass in front of the plane of the body of their vertebra are—the 1st, $4\frac{1}{2}$ inches; the 3rd, $5\frac{1}{2}$; the 5th, $3\frac{1}{2}$ (angle 40°); the 7th, $1\frac{1}{2}$; the 9th, 1 inch. The 10th is nearly straight out. The backward direction begins on the 11th and 12th. The backward direction of the posterior border begins on the 8th. On the 11th, the most prominent parts of the process are, respectively, $\frac{1}{4}$ inch behind the front of the body and $\frac{1}{2}$ inch behind the back of the body. Behind this, the backward direction of the processes is much less than in Megaptera. The posterior part of the process is 1 inch behind the body on the 13th (angle 5°); on the 14th, $\frac{3}{4}$ inch; on the 15th, it is $\frac{3}{4}$ inch in front of the back of the body.

Form.—The prismatic form is well marked on the 3rd and 4th, on their inner half, and throughout on the 5th and 6th, especially at their outer part. Behind the 6th the processes grow thinner and thinner by the gradual disappearance of the lower edge of the prism.

Seen from below, the processes, from the 2nd backwards, are concave as far out as the beginning of the costal fossa, though very shallow after the 9th. In Megaptera, after the 5th, the processes appear convex below from the upturning of the process and the far in position of the costal fossa. The form of the processes is further noted with the breadth.

Length, Breadth, and Thickness of the Dorsal Transverse Processes.—In *length*, the processes increase to the 13th, and begin to diminish after the 14th. In *thickness* (vertical measurement, taken at the middle), the 5th is much the greatest, behind which there is rapid diminution. In *breadth*, which is their most remarkable character, they increase backwards to the 11th (7½ inches), and then diminish backwards. The expansion is rapid on the 6th (breadth, 6 inches). From the 7th to the 14th the difference is not great. From the 9th to the 13th there is almost no difference in the breadth of the neck of the process (about 4½ inches). On the 11th the wing is within about an eighth part of being twice as broad as the neck; and from the 7th to the 11th the breadth of the wing is within ¼ inch of being as great as the length of the body. The anterior intertransverse projection, or angle, marking off the two stages of the process, is about the middle of the border. The projection on the posterior border is internal to the middle, is well enough seen on most of the processes, and gives the undulatory form to this border. The anterior half of the wing is thin. The beam of the process runs out from the neck to opposite the costal fossa, which it supports. The expansion on one side of the process tends to alter its direction, compared with that of a process which has the beam only. In the articulated skeleton, the spaces between the processes, from the 6th backwards, are, between the necks, about equal to the breadth of the neck; between the wings they average about 1½ inch, being less than a fourth part of the breadth of the processes. That this remarkable expansion of the outer half of the dorsal transverse processes in B. musculus, compared with Megaptera, is not merely a distinction of age is evident from the fact that, while in this B. musculus the anterior border of the wing has the appearance of a part from which a strip of cartilage has been removed, the anterior border in Megaptera has already a finished appearance.

Costal Fossæ.—The costal fossæ are very different from those of Megaptera. They are most characteristic from the 6th to the 10th. They are placed on about the posterior half of the broad end of the process, rather than below it, and are elongated antero-posteriorly. (On the 7th, length, 4 inches; vertically 3 inches; depth, ¾ inch.) A rounded-off angle below gives the fossa a low triangular form, changing to the elliptical as we go back from the 9th and 10th. The overhanging arched upper boundary has very little of the obliquity seen in Megaptera. The whole outer margin of the broad wing has a gently sigmoid form, the posterior half, or a little more, above the costal fossa. The fossæ look mainly outwards, with a lesser degree of direction backwards and downwards. The outer margin of the processes, though not fully ossified, are much sharper than in Megap-

tera. On the 7th, over the middle of the costal fossa, the margin is ¼ inch thick. On the 12th, 13th, and 14th they are narrow elliptical facets, very shallow; on the 13th and 14th quite on the end of the process and looking straight outwards. The transverse process of the 15th bears no mark for its rib, and is very little thicker than that of the first lumbar. The anterior half or two-thirds of the fossæ have been covered with cartilage; when the 12th is reached the whole area has been so. This contrasts with Megaptera in which the fossæ do not present the appearance of having been covered by cartilage.

25. LUMBO-CAUDAL TRANSVERSE PROCESSES IN B. MUSCULUS.—*Origin.* —Like the hinder dorsal, they are on a line with about the middle of the bodies. They spring nearer the front than the back of the bodies, a little on the 1st lumbar, increasing in this respect back to the 11th; less so on the three next; on the 15th rather the reverse; from the 1st caudal to the 6th, decidedly nearer the back of the body, this being due to the greatly increased depth of the anterior concavity after the vertical foramen has opened into it. After the 7th caudal, in which that foramen pierces the process, the process springs much nearer the front than the back of the body.

The forward *direction* begins with the 3rd lumbar, and increases to the 7th. From the 10th the forward direction lessens, and at the 15th is very slight. On the first six caudal the processes are on the whole horizontal, varying a little according as the anterior or posterior corners are most developed. Behind the 6th the direction of the processes is noted with their form. In *length*, they diminish a little from the 1st to the 10th lumbar, and from the 11th rapidly backwards. The thickness is about half that of the dorsal processes. In *breadth*, they vary little from the 1st lumbar to the 3rd caudal, averaging about 6½ inches; the 13th and 15th lumbar have the exceptional breadth of 7 inches. The regained breadth of the 7th caudal, and of the three or four behind it, is owing to the change of form consequent on the vertical foramen.

Form.—The lumbo-caudal processes, back to the 6th caudal, present the same flattened and outwardly expanded form as the posterior dorsal processes, but are thinner all along the process. Back to the 12th lumbar the wing is less square-shaped, as the expansion is less and also more gradual. The distinction between neck and wing is less marked, but the anterior intertransverse projection is recognisable, and the projection on the posterior border is rather better marked than on the dorsal processes. Behind the 12th, the lumbar processes become more convex externally from the rounding off of the angles. The first six caudal show this degeneration to a greater extent; the neck shortens, and the wing-stage is represented only by a semicircular end beyond the anterior and posterior intertransverse projections. The anterior concavity of the neck deepens, and on the 7th caudal, is enclosed, forming the foramen of the vertical passage. The stunted processes behind this, having the foramina, are very broad, springing now from as far forward as where the body joins its epiphysis. Behind the 8th, however, the foramen is at or behind the middle of the process.

General Survey of the Transverse Processes in B. musculus.

Viewed from the caudal end and from above, the general outline of the transverse processes shows but little of that convexity presented by the processes of the lumbar and anterior caudal regions of Megaptera, or by the whole sweep of the outline in B. borealis from the neck to nearly the middle of the caudal region. In this B. musculus the outline is nearly flat from about the 12th dorsal back to nearly the end of the long lumbar region; and along the caudal region the outline tapers gradually backwards, with very little convexity. If compared to an ellipse, it would be the hinder half of a very narrow ellipse, beginning at the 13th dorsal vertebra. Only the 13 or 14 posterior caudal vertebræ appear destitute of transverse processes, giving a length of 4½ to 5½ feet, as compared with the 7½ feet of Megaptera, without transverse processes. Viewed from the atlantal end, the eye would take the 8th dorsal for the widest, and recognises very little diminution on the 7th and 6th. The dorsal region as a whole shows a figure bounded by a gently convex outline. Viewed from above or below, the great breadth of the transverse processes contrasts strongly with their little expansion in Megaptera. The difference is least in the posterior lumbar region in Megaptera, but is great throughout.

SPINOUS PROCESSES.

26. FORM.—The most striking character of the spines in Megaptera is their narrowness and but little of that expansion at the end which B. musculus shows to so great an extent. This may be in part owing to incomplete ossification in this Megaptera, but the exposed surface from which the cartilage has been removed belongs to the top with a tapering prolongation below the posterior angle for about 1 inch only. Further ossification would increase the length, but it could not well give a terminal expansion so great as in B. musculus, so as to bring the expanded ends nearly in contact, or actually so, for from 3 to 5 inches down from the top. Taking the last dorsal vertebra, the breadths at the middle and at the end are—in Megaptera, 4¼ and 5½ inches; in B. musculus, 5¼ and 8¼. In the articulated skeleton the intervals between the end of the dorsal processes are fully 2 inches, while in B. musculus the expanded ends may be in contact or about 1 inch apart. Rudolphi's figure of the skeleton of Megaptera shows the spines almost square-topped, and not broader at the top than at the middle. In the figure of the skeleton by Van Beneden and Gervais (pls. x. and xi.) the tops of the spines are less rounded, but not more expanded than in this Megaptera. Their figure of

B. musculus (pls. xii. and xiii.) does not show the great expansion of the ends of the spines presented by this B. musculus.

27. LENGTH, BREADTH, AND THICKNESS OF THE SPINOUS PROCESSES.—In *length* the processes increase from the 1st dorsal (3½ inches) to the 5th lumbar (the 5th, 6th, and 7th lumbar each 14 inches), and decrease from the 8th lumbar to the 10th caudal (¾ inch). The longest transverse processes are the six before the above group of longest spinous processes.

The *breadth* of the processes at their middle does not vary much from the middle of the dorsal region to the earlier part of the caudal, the broadest being the last lumbar and 1st caudal (5½ inches). The expansion at the top follows the same order, about ½ inch to 1 inch broader than at the middle. The 8th and 9th dorsal come in exceptionally as broad at the top (6 inches) and are nearly as broad at the middle (5¼ inches) as the last lumbar and 1st caudal.

In *thickness* the spines increase backwards to the 1st lumbar, and decrease backwards from the 2nd, but the difference is not great. From the 4th to the 7th dorsal it is 1 inch; on the next three, it is 1⅛ inch; on the remaining four dorsal, 1¼ inch; on the 1st and 2nd lumbar, 1⅜ inch; on the 3rd to the 8th lumbar, 1½; on the 3rd and 4th caudal it is again 1 inch.

The thicker part of the process is generally behind the middle. This is seen on the top by the generally greater thickness of the posterior third of the border, giving it a narrow ovoid form. This *ovoid upper margin* is seen from the 8th dorsal to the 8th lumbar (10th dorsal, at middle 1 inch, behind 1⅛; 14th dorsal 1¼ and 1½), is most marked on the 1st lumbar (1¼ and and 1⅝), and then diminishes backwards. From the 9th lumbar to the 2nd caudal it is absent, and is again seen to a moderate extent on the spines behind that. On the last dorsal and two first lumbar, the thick part of the ovoid end is thicker (by ⅔ inch) than the thickest part of the middle of the shaft; but, taken at the middle of the ovoid, so as to give an average thickness, the end of the spinous process is generally thinner than the shaft by from ⅛ to ⅜ inch.

28. DIRECTION OF THE SPINOUS PROCESSES.—The spines of the 1st, 2nd, and 3rd dorsal are directed backwards, owing to the greater slope of their anterior border. The 4th, at first some-

what triangular, is directed straight up; the 5th, now square-shaped, a little forwards; the 6th, straight up; the 7th, a little backwards. The remaining spines all slope backwards, increasingly so to the 14th dorsal. After the 1st lumbar the slope diminishes a very little to the 6th, then a little more to the 9th, and still more from the 10th lumbar to the 3rd caudal. Behind the latter the slope begins to increase, but the processes are too irregularly formed to give precise indication.

A convenient way of measuring the amount of the slope is to take a perpendicular from the plane of the back of the body. But the result by this method is influenced by the length of the spine, and in Megaptera (as compared with B. musculus) by the length and backward obliquity of the laminæ in the dorsal and anterior lumbar regions, thus carrying the base of the spines backwards in these regions as compared with the middle and posterior lumbar regions. The result by the perpendicular line, therefore, does not always correspond to the real obliquity, as ascertained by taking the angle.

The figures in the first column of the subjoined table (Table IV.) give the distance of the *back* of the body behind the *middle* of the top of the spine; the second column gives the true obliquity, the angle formed by the axis of the body and the axis of the spinous process. For comparison, the same measurements in B. musculus are given.

TABLE IV., *giving the Amount of Obliquity of the Spinous Processes in Megaptera and B. musculus.*

Vertebra.	Megaptera.	Angle.	B. musculus.	Angle.
1st dorsal,	1 inch behind, . .	75°	2 inches in front, .	100°
6th ,,	1 inch in front, . .	90°	2 ,, ,, .	90°
9th ,,	Same plane, . .	80°	1½ ,, ,, .	88°
11th ,,	1 inch behind, . .	65°	Same plane, . .	70°
14th ,,	3½ ,, ,, (greatest),	55°	2 inches behind, .	65°
3rd lumbar,	2½ ,, ,, . .	56°	4 ,, ,, . .	57°
6th ,,	1½ ,, ,, . .	57°	4½ ,, ,, . .	54°
10th ,,	Same plane, . .	65°	5½ ,, ,, . .	50°
11th ,,	,, ,, . .	...	6½ ,, ,, (greatest),	46°
1st caudal,	½ inch in front, . .	68°	2½ ,, ,, . .	55°
3rd ,,	1 ,, ,, . .	70°	½ ,, in front .	60°
6th ,,	2 ,, ,, . .	60°		55°

Besides the points above referred to, the following may be noted of the *form* of the spinous processes. *Anterior border,*

3rd and 4th more so, the 5th to the 8th decidedly forwards (angle at the 7th, about 22°), the 9th a little, the 10th very little. The direction of the caudal transverse processes is variable, depending on the non-development of the anterior or posterior angles of the wing, external to the intertransverse projections. The direction of the 1st is straight out; that of the 2nd and 3rd backwards, owing to the failure of the anterior angle of the wing; that of the 4th a little forwards, that of the 5th and 6th very much forwards, owing to the want of the posterior angle and of almost the whole of the wing, and to the great depth of the anterior concavity of the neck. The 7th and 8th are mere lateral ridges. The change of the posterior border to the backward direction begins on the 9th lumbar and continues to the 4th caudal.

In *length* the processes continue the same as the last dorsal to the 3rd or 4th lumbar, after which they diminish; after the 6th lumbar rapidly, after the 3rd caudal very rapidly. On the 6th caudal they are very short, on the 7th and 8th they are represented by a mere tubercular trace. In *breadth* they increase a little by expansion of the outer half, to the 8th lumbar, after which the breadth diminishes as we go back. In *thickness*, taken at the middle, they are pretty uniform. On an average the thickness is about 1 inch, about half that of the dorsal transverse processes.

In *form* the processes show more than in the dorsal region the distinction between neck and wing, as they broaden outwardly and shorten, on the posterior lumbar and anterior caudal region. On the anterior border, the intertransverse projection becomes more marked on and after the 9th lumbar, from the falling away of the wing external to it. This becomes more marked on and after the 1st caudal, giving the anterior border a backward direction external to the projection. Thus the typical sigmoid form of the border becomes more marked backwards. From the 9th lumbar backwards, the concavity is more striking, partly from being deeper, partly from now occupying a greater proportion of the length of the now shortening processes. From the 3rd to the 6th caudal, the concavity becomes increasingly deep and narrow, and on the 5th is manifestly the opening out of the vertical passage seen on the vertebræ behind it. On

the posterior border, the intertransverse projection is seen in various degrees, giving the wavy outline.

The ends are all convex and incompletely ossified, except the 5th and 6th caudal, which are sharply finished. The unfinished state being only at the ends seems to indicate that further ossification would have added to the length but scarcely to the breadth of the processes. On the whole, these processes do not expand much, although on the last five lumbar it is noticeable enough. The breadths of the narrowest and broadest parts of the process, respectively, are—of the 1st lumbar, $3\frac{1}{4}$ and 4 inches; of the 8th, which has the greatest expansion, $3\frac{1}{2}$ and $5\frac{1}{2}$; of the 10th, $3\frac{5}{8}$ and $4\frac{6}{8}$.

Comparing the breadth of the lumbar processes at their outer half with that of the spaces between them, the first two spaces are rather less than the processes; the five next about equal. From the 8th vertebra backwards, the spaces become wider and wider compared with the processes. Between the first five caudal the spaces are two to three times as wide as the processes. This depends not only on the processes becoming narrower, but on the increased distance in the caudal region between the bodies of the vertebræ.

22. GENERAL SURVEY OF THE TRANSVERSE PROCESSES IN MEGAPTERA.—Viewed from the caudal end and from above, the extreme outline of the processes, from the last costal vertebra backwards, has the figure of the hinder half of an ellipse, the convex edges tapering very rapidly on the 4th, 5th, and 6th caudal, the latter being the first which shows a prominent transverse process. This view of Megaptera is remarkable for the absence of transverse processes on the fifteen posterior caudal vertebræ, a space of about $7\frac{1}{2}$ feet, giving the caudal vertebræ a clipped appearance. Forwards, what strikes the eye is the upturning of the dorsal transverse processes, becoming very marked on the 12th. At the same time the outline figure narrows forwards to form the fore part of the ellipse, but the tilting up of the dorsal processes breaks the outline. Viewed from the atlantal end, the upturning of the dorsal processes is still more apparent, rising like the ribs of a ship. The outline along the dorsal processes shows contraction forwards, but not much convexity. To the eye the 14th dorsal seems the widest,

with diminution immediately behind and before. The eye does not detect that the first three lumbar are equally wide, nor would the eye detect so great a diminution as 6 inches from the 14th to the 8th dorsal.

23. TRANSVERSE PROCESSES IN B. MUSCULUS COMPARED WITH THOSE OF MEGAPTERA.

The transverse processes differ much from those of Megaptera, in expansion of their outer two-thirds, in being much thinner, and in being very little turned upwards in the dorsal region.

24. DORSAL REGION.—*Origin.*—The root common to the pedicle and the transverse process on the first four is more oblique than in Megaptera. On the 7th, the pedicle and the process are as distinct as on the 8th of Megaptera. Behind this, as seen from above, the processes spring from lower on the bodies than in Megaptera. This is owing to their thinness. Seen from below, they do not spring so high from the bodies as in Megaptera, but from the 4th to the 13th their line of origin is slightly convex upwards. At the 15th, the process is thin enough to have fallen quite to the level of the middle of the body.

Direction.—The first is straight. The three first are decidedly concave above. Viewed from above, the processes appear to the eye to rise outwardly from the 5th to the 12th, but it is from the 7th to the 13th that the outer end of the process is really higher than the inner part, the 13th very little. The rise above the costal fossa renders the outer half concave. From the 6th, diminishing backwards, the inner half of the process is rather convex. A line from tip to tip of the transverse process of the 10th shows a rise of $1\frac{1}{2}$ inch from the neck to the tip of the process. The line is on a level with the body at its hinder edge and $1\frac{1}{2}$ inch below the articular process. The concavity is about $\frac{1}{4}$ inch deep. On the 7th it is twice that, the depth increasing forwards owing to the inward rise of the process to the articular process. Viewed from below, the processes rise a little outwardly from the 7th to the 13th. The *forward direction* of the processes is greater than in Megaptera. The distances to which the processes pass in front of the plane of the body of their vertebra are—the 1st, $4\frac{1}{2}$ inches; the 3rd, $5\frac{1}{2}$; the 5th, $3\frac{1}{2}$ (angle 40°); the 7th, $1\frac{1}{2}$; the 9th, 1 inch. The 10th is nearly straight out. The backward direction begins on the 11th and 12th. The backward direction of the posterior border begins on the 8th. On the 11th, the most prominent parts of the process are, respectively, $\frac{1}{4}$ inch behind the front of the body and $\frac{1}{2}$ inch behind the back of the body. Behind this, the backward direction of the processes is much less than in Megaptera. The posterior part of the process is 1 inch behind the body on the 13th (angle 5°); on the 14th, $\frac{3}{4}$ inch; on the 15th, it is $\frac{3}{4}$ inch in front of the back of the body.

Form.—The prismatic form is well marked on the 3rd and 4th, on their inner half, and throughout on the 5th and 6th, especially at their outer part. Behind the 6th the processes grow thinner and thinner by the gradual disappearance of the lower edge of the prism.

Seen from below, the processes, from the 2nd backwards, are concave as far out as the beginning of the costal fossa, though very shallow after the 9th. In Megaptera, after the 5th, the processes appear convex below from the upturning of the process and the far in position of the costal fossa. The form of the processes is further noted with the breadth.

Length, Breadth, and Thickness of the Dorsal Transverse Processes.— In *length*, the processes increase to the 13th, and begin to diminish after the 14th. In *thickness* (vertical measurement, taken at the middle), the 5th is much the greatest, behind which there is rapid diminution. In *breadth*, which is their most remarkable character, they increase backwards to the 11th ($7\frac{1}{2}$ inches), and then diminish backwards. The expansion is rapid on the 6th (breadth, 6 inches). From the 7th to the 14th the difference is not great. From the 9th to the 13th there is almost no difference in the breadth of the neck of the process (about $4\frac{1}{2}$ inches). On the 11th the wing is within about an eighth part of being twice as broad as the neck ; and from the 7th to the 11th the breadth of the wing is within $\frac{1}{4}$ inch of being as great as the length of the body. The anterior intertransverse projection, or angle, marking off the two stages of the process, is about the middle of the border. The projection on the posterior border is internal to the middle, is well enough seen on most of the processes, and gives the undulatory form to this border. The anterior half of the wing is thin. The beam of the process runs out from the neck to opposite the costal fossa, which it supports. The expansion on one side of the process tends to alter its direction, compared with that of a process which has the beam only. In the articulated skeleton, the spaces between the processes, from the 6th backwards, are, between the necks, about equal to the breadth of the neck ; between the wings they average about $1\frac{1}{2}$ inch, being less than a fourth part of the breadth of the processes. That this remarkable expansion of the outer half of the dorsal transverse processes in B. musculus, compared with Megaptera, is not merely a distinction of age is evident from the fact that, while in this B. musculus the anterior border of the wing has the appearance of a part from which a strip of cartilage has been removed, the anterior border in Megaptera has already a finished appearance.

Costal Fossæ.—The costal fossæ are very different from those of Megaptera. They are most characteristic from the 6th to the 10th. They are placed on about the posterior half of the broad end of the process, rather than below it, and are elongated antero-posteriorly. (On the 7th, length, 4 inches ; vertically 3 inches ; depth, $\frac{3}{4}$ inch.) A rounded-off angle below gives the fossa a low triangular form, changing to the elliptical as we go back from the 9th and 10th. The overhanging arched upper boundary has very little of the obliquity seen in Megaptera. The whole outer margin of the broad wing has a gently sigmoid form, the posterior half, or a little more, above the costal fossa. The fossæ look mainly outwards, with a lesser degree of direction backwards and downwards. The outer margin of the processes, though not fully ossified, are much sharper than in Megap-

PROCEEDINGS OF THE

ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

An Ordinary Meeting of the Society was held in the Library of St Bartholomew's Hospital, on Wednesday, April 18, 1888—President G. M. Humphry, F.R.S., in the Chair. Present—Thirty-two members and visitors. The minutes of the previous meeting were confirmed. The following gentlemen were declared to have been elected members of the Society :—H. Duncan, Humphry Broomfield, Bernard Lawson, Gordon C. Brodie, John S. Morgan, Dr Thompson, A. W. Cadman, James W. Groves.

Mr J. Bland Sutton then discussed the *Morphology of the Deep Extensors of the Fore-Arm*, in connection with Mr St John Brooks's paper read at the previous meeting (*Proceedings*, p. xv), and said,— Mr Brooks bases his arguments on facts derived from amphibian and reptilian myology supplemented by the Edentates. I learnt long ago that one could prove almost any view concerning particular muscles by dissecting lizards and amphibians. These forms are invaluable when we have to deal with general questions of myology, but are useless for illustrating particular cases. Mammalian myological questions must, so far as particular groups of muscles are concerned, be studied in mammals. To choose Edentates is very risky, for though they are undoubtedly very archaic, nevertheless the forms are very aberrant, and even those most enthusiastic in admiring this group are bound to admit that it is for the most part a heterogenous collection.

Dr St John Brooks replied that Mr Sutton had not taken exception to his paper as a whole, but only to one particular point. This point, however, was a vital one. According to Mr Sutton the deep extensor muscles arose originally from the humerus and migrated *downwards*. In the speaker's opinion they were originally situated on the dorsum of the hand, from whence they migrated *upwards*. Dr Brooks believed that the President had formed a similar theory to the one he was advocating, and read an extract from the *Journal of Anat. and Phys.*, vol. vi., in support of this. He considered, in fact, that he had re-stated Professor Humphry's views, and added some additional evidence. In some points, however, his opinions were at variance with Professor Humphry's; for instance, he believed the extensor minimi digiti to be morphologically part of the deep layer, while Professor Humphry regarded it as a part of the superficial layer. He was glad to see that Mr Sutton

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agreed with him in placing it with the deep group. Professor Ruge had advanced a very similar theory, in regard to the deep extensors of the toes, to Mr Sutton's theory of the descent of the deep extensors of the fingers. Ruge believes that the extensor brevis digitorum (pedis) was originally a peroneal muscle which gradually made its way downwards to the dorsum of the foot. He would deal with Sutton's and Ruge's theories together. If we confined our attention to mammalian myology there was much to be said in favour of these theories, particularly in the case of the foot (Ruge's theory). But an examination of reptilian and amphibian myology showed these theories, in the speaker's opinion, to be quite untenable: in all these animals there was an extensor brevis digitorum both in the hand and the foot, which could be seen in the lizards, gradually extending its origin upwards to the fore-arm and to the leg. Dr Brooks then showed a number of drawings and diagrams illustrating these points, and invited the meeting to compare these drawings with the dissected specimens which he had brought to the meeting. Dr Brooks then said that although the Ornithodelphs and Marsupials departed widely from the Reptiles in the case of these particular groups of muscles, the Edentates (an archaic order of Mammals), on the contrary, showed remarkable reptilian characters, and he pointed out the strong resemblance between a figure of the foot and leg of the Great Ant-Eater (Macalister, in *Trans. Roy. Irish Acad.*, vol. xxv., plate xxvi. fig. 5) and one of his own drawings of the corresponding part in Hatteria. In one point he considered Mr Sutton's views to be particularly erroneous, when he said that "as the muscles descended they carried with them a branch of the musculo-spiral nerve, the posterior interosseous." The speaker had found the posterior interosseous nerve supplying both the muscles and integument on the dorsum of the hand in Reptiles and Amphibia, as could be seen in the diagram of Hatteria which he had already shown. How then could the nerve have been "carried down" in the higher mammals when it was not only already *down* but relatively *much larger* in primitive forms?

Professor THANE was of opinion that the disposition of the muscles in Reptilia and Amphibia was important, as throwing light on the origin of the corresponding parts in the Mammalia, and that the tendency of the more prevalent variations in man was to support Dr Brooks's view that the deep extensors were primitively short muscles.

Mr LOCKWOOD asked whether he had correctly understood Mr Sutton to say that the posterior interosseous ganglion was the remains of the deep extensors of the human subject. He thought the fact that, in some types, the posterior interosseous nerve supplied digital cutaneous branches, although the deep extensors had, at the same time, a high attachment, disposed of Mr Sutton's theory.

Professor G. B. HOWES inclined towards an acceptation of Mr Brooks's views; and attached considerable importance to the evidence adduced by him from the Edentata, in consideration of the accepted views of the structural lowliness of that group. He also pointed out

the advisibility of examining the parts in the *Dasyuridæ*, and especially in the Banded Ant-Eater (*Myrmecobius*), that animal being, in its dental characters, identical with the oldest known Mesozoic mammals.

The following papers were then read :—

Rabbit with an Undescended Testis, with Notes on the Descent of the Testis in the same Animal. By M. F. WOODWARD, Demonstrator of Zoology, Normal School of Science and Royal School of Mines.

Among a number of adult rabbits recently obtained for dissection in the Biological Laboratory at the Normal School of Science, my attention was called to the one forming the subject of these notes; it is exceptional in being, so far as I am able to discover, the first adult rabbit in which the existence of an undescended testis has been recorded. The testis and scrotal sac of the right side were well developed; the left testis was small, and occupied a position normal to the ovary. On careful examination the specimen proved to be a male of from five to six months, and consequently sexually adult, for the rabbit is capable of breeding at the age of four months. The external genital organs were rather small, and the right scrotal sac was alone visible. The testis of the right side (*t.r.*) was fully formed, and had descended completely to the bottom of the afore-named sac, as usually happens only when the animal is in breeding condition. It was somewhat curved, and measured 33 mm. in length, including the epididymis, and 10 mm. in breadth; the vas deferens, uterus masculinus, prostate, and Cowper's glands were all in the normal condition, but small. Of the left scrotal sac there was no sign; the left testis (*t.l.*), which was very long and narrow, measured with the epididymis 36 mm. in length and 6 mm. in width; it was situated in the body-cavity, immediately behind the kidney, and to this it was attached by a fold of mesentery, the *plica vascularis*. It was suspended to the dorsal body-wall by the mesorchium, and hung down freely, closely resembling the ovary in position and size.

The spermatic artery (*s.a.*) and vein, instead of running back as they did on the other side, ran directly outwards and slightly forwards, and in fact retained their primitive position, showing the genital gland itself to have remained undisturbed. The epididymis was small in calibre, but relatively long, as the tubes composing it were loosely coiled; its cauda, which was much the longest segment, gave origin to the vas deferens (*v.d.*), and this, passing directly back to the uterus masculinus, crossed the ureter near the bladder. A little above that point, it received a branch from the inferior vesicular artery, which could be traced anteriorly as far as the cauda itself.

Skirting the free ventral border of the mesentery suspending the left vas deferens there was a flat band of muscular connective-tissue

(*g.*) attached anteriorly to the cauda epididymis; posteriorly it passed through the inguinal canal (*i.c.*) (which was rudimentary, and measured 12 mm. across), and then spread out in the region of the symphysis pubis. This band is the *gubernaculum testis*, and it

Urinogenital organs of a male rabbit, with an undescended testis on the left side, half its natural size.

measured 45 mm. in length. The processus vaginalis was very slightly developed, and in no way in excess of that seen in some females.

A microscopic examination of the undescended testis showed that the seminal tubules were lined by a well-developed germinal

epithelium, and in most cases a second irregular layer could be recognised, evidently budded off from the first, but destitute of the characters of the proliferating layer of the adult tubule. There were no traces of either the "nutritive" layer or of developing spermatozoa. The testis showed, however, no signs of actual degeneration, and I assume that it might have become functional had the animal grown older.

The testes in the rabbit begin to descend during the last week of intrauterine life, and at birth they come to lie just at the entrance of the inguinal canal. They pass into this about the second week after birth; but it is not till the animal is about a month old that they descend into the scrotal sacs, and even then they are so small that their presence is not perceptible externally. This becomes clearly obvious at the end of the second month, and by the time the animal is four months old it is sexually mature, though by no means full grown.

Hunter was the first to describe in detail (*Animal Economy*) the descent of the testis in the human subject, and he also noted the relations of the gubernaculum and processus vaginalis. The descent of the testes in the rabbit does not seem to have been hitherto described. It appears to take place in practically the same manner as in the human subject; it is, however, more difficult to distinguish between the sexes in the early stages, on account of the great development in the female of the round ligament and processus vaginalis.

It is worthy of note here that in some mammals the testes are retained permanently within the body-cavity, never descending into the scrotal sacs at all. Those mammals possessed of this peculiarity are termed by Owen and Milne Edwards the "*Testiconda*"; they embrace the Proboscidea, Cetacea, Sirenia, Edentata, and Monotremata; and the genital glands occupy somewhat different positions in the different members of the series. In the Insectivora, on the other hand, the testes descend into the inguinal canal, but no scrotal sacs are formed. In the rabbit they descend to the bottom of the scrotal sacs during the rut, lying at other times in the neck of the inguinal canal. From this, however, they are never fully retracted.

It is interesting to comment, in the light of the foregoing, upon the existence in an adult mammal of conditions so diverse as are those of opposite sides of the one under consideration. Whether, however, the undescended testis ever becomes functional, it is doubtful; precedent would seem to indicate that it does not.

References.—MILNE EDWARDS, *Physiol. et l'Anat. Comp.*, tom. 9, p. 3. J. HUNTER, "Descent of the Testicle," in *Animal Economy*, Lond., 1786. KÖLLIKER, *Entwicklungsgs.*, 1861, p. 453. LOCKWOOD, C. B., *Development and Transition of the Testis, Jour. Anat. and Phys.* vol. xxi. p. 635, vol. xxii. pp. 38, 481.

Undescended Right Testicle, Hypertrophy of the Left One in a Monkey.
By Walter K. Sibley, B.A., M.B., B.C. Camb.

The specimen is taken from a Bonnet Monkey (*Macacus sinicus*) which had lived in the Zoological Society's Gardens some four years, and died from visceral tuberculosis. The bones were soft and deformed. The scrotum was distended, and contained only one (the left) testicle, which was considerably and uniformly enlarged. This together with the epididymis weighed some 17 grammes. It was rather soft, but upon section revealed normal tubular tissue. There was no fluid in the tunica vaginalis nor adhesion of its layers; the cord was normal; there was no hernia or other abnormality about the scrotal

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Fig. 1.   *f*   Fig. 2.

Fig. 1.—Undescended Testicle in a Monkey (reduced in size), left testicle showing considerable hypertrophy of its body.
Fig. 2.—Right Testicle with Broad Mesorchium (reduced in size). *a*, body of testis; *b*, globus major; *c*, globus minor; *d*, vas deferens; *e*, blood-vessels and remains of embryonic structures; *f*, gubernaculum.

contents. This hypertrophied testicle was twice the size of a normal one in this form of monkey (fig. 2). The right testicle was lying in the abdominal cavity below the kidney of this side, attached to the posterior abdominal wall by a broad mesorchium containing in its folds the blood-vessels and embryonic remnants together with the vas deferens and gubernaculum (fig. 1). This testicle, together with its adjacent appendages, weighed under 5 grammes, thus not a third the weight of its fellow. In consistence it was firm upon section, showed normal tubular substance. The epididymis was large in proportion to the testicle, not being arrested to the same degree in its development.

Histologically, both testicles consisted of typical glandular tissues.

All parts of the body, especially the muscles, undergo a process of

hypertrophy when subjected to increased and intermittent metabolism. But this change is not so generally attained by the nervous and glandular organs. The viscus most usually given as an example of physiological hypertrophy is the kidney. If one kidney be absent, or from any cause be prevented from performing its part in the animal's economy, the other kidney generally taking on increased function becomes enlarged, that is hypertrophied, not only as to its elementary cells, but also in the actual numbers of the glomeruli and tubules.

But this process is not usually described as taking place in the testicle.

Few writers on the subject speak of an hypertrophy of the testicle following the removal or arrested development of its fellow, in fact many doubt it ever occurring.

Curling,[1] however, relates a case in a Monorchis (where no trace of a second testicle could be found upon dissection) of a marked hypertrophy of the existing one; he also quotes three examples of an enlargement of a single testicle in cases where the other one was undescended, and offers as an explanation of the usual non-occurrence of compensatory hypertrophy, "that it is due to the bounty of nature in all that concerns reproduction, one testicle being sufficient for manhood"; he adds, "it is not surprising, therefore, that in cases of absence or imperfect development of one testicle the other does not as a rule exceed the normal size."

Sutton,[2] in his *General Pathology*, refers to the rare specimen in the museum of the College of Surgeons of an hypertrophied testicle of a Monorchis which weighed considerably over 2 ounces.

Cohnheim[3] speaks of hypertrophy of the testicle following increased blood-supply, but does not give any references.

There is no obvious reason why the testicle should not hypertrophy as well as any other glandular organ; it does not in any way differ embryologically or physiologically from other tissues under normal conditions, why then should it under slightly altered ones go off along a path of its own?

Organs called into more active use enlarge, but it is generally stated that under the same circumstances the testicle becomes smaller. And so, conversely, that text-books usually pass over hypertrophy as if the writers did not believe it ever occurred.

In the case of birds and many lower animals the testicles undergo very marked periodic hypertrophy during the breeding season.

In birds at this time the testicles usually occupy a very considerable and conspicuous part of the abdominal cavity, and at other times are insignificant.

It seems probable that this subject in human pathology has been overlooked, and a statement once having been made it has been repeated, but without any fresh evidence.

[1] Curling, *Diseases of the Testicle*, 1866, p. 59.
[2] Bland Sutton, *General Pathology*, 1886, p. 13.
[3] Cohnheim, *Allgemeine Pathologie*, p. 697.

It is in order that cases of this nature may be noted that I have thought it worth while bringing this subject forward.

On the other hand, atrophy of the testicle is generally admitted to be common and to arise from many causes, as from acute orchitis, especially that accompanying or following parotitis in young men, also from chronic epididymitis. So again the testicle when retained in the inguinal canal or in the abdomen, or when in the scrotum with a congenital hernia, is small from pressure on its blood-vessels; also in cases of varicocele the testicle slowly becomes smaller.

English and continental observers are not agreed as to which of the testicles is the more usually retained, thus Godard collected twenty-two cases of undescent in the left and fourteen in the right. On the other hand, Ezgmanowski published forty-five cases occurring on the right side and only twenty-two on the left.

Mr C. B. Lockwood showed specimens to illustrate the transition of the testes :—(1) An anencephalic human fœtus, in which the scrotum was ill developed and the left gubernaculum unattached to the testicle. (2) Retained testicle (abdominal inclusion) from youth of eighteen. The testicle lay in the iliac fossa, but the processus vaginalis was 4 inches long and protruded from the external ring. The vas deferens looped down almost to the end of the processus, and a strong band of muscular fibres was attached to the end of the loop. (3) Gubernaculum of rabbit's embryo, showing ascending cremaster.

The Depth of the Cortex of the Kidney.   By JOHN FLETCHER LITTLE.

Having had occasion to investigate a question relating to the naked-eye appearances of the healthy kidney, I found that no two authors whose works were accessible to me agreed as to the normal depth of the cortical substance. In the last edition of Quain it is stated that it measures 2 lines. In the 1887 edition of Gray it is put down as being from one-third to one-half an inch; and in several authors—Turner, Heath, Cantlie, Bellamy, and Treves—I failed to find any measurement of it at all.

Under these circumstances I thought it best to make a collection of healthy kidneys, taken from the bodies of those who had died from diseases other than renal, or had met with fatal accidents whilst in perfect health. The accompanying series of twelve kidneys were selected by Dr Montague Murray, the pathologist to Charing Cross Hospital, and Mr Anthony Bowlby, pathologist to St Bartholomew's, as presenting all the characters of the healthy organ. The causes of death and ages of the patients are as follows :—Epithelioma of fauces (50), burn with phosphorus (68), fractured base of skull (35), atheroma of aorta (42), fractured skull and meningitis (30), compound fracture of thigh (77), fractured skull and jaw (63), cellulitis right hand and arm (39), injuries to head (30), phthisis (19), fractured base of skull (?).

The average dimensions of these kidneys agree with those which are regarded by all as normal, i.e., 4 inches by 2 inches by 1 inch. The colour, capsules, weight, and consistence are also normal. What then is the average depth of the cortex lying between the capsule at the outer border and the bases of the pyramids of Malpighi as seen in these kidneys? It will be found that no measurement is so low as 2 lines and none so great as 6. They vary from a little under 3 lines to a little over 5 lines, and the great majority of them are 4 lines. In fact, the average is as nearly as possible 4 lines, or *one-third of an inch*.

All this is quite in accordance with my experience when, as Medical Officer to the Constabulary, I made many *post-mortems* on the bodies of those who had met with violent or sudden deaths. I do not remember any kidney which presented all the other signs of health, having a cortex of only two lines nor one which reached the extreme of half an inch. Should further research, supplemented by the experience of the members of the Anatomical Society, confirm this view, we must admit that the average depth of the normal cortex should be described as one-third of an inch.

In conclusion, it may not be out of place here to state that very vague ideas obtain both in the profession and outside it as to the length of a line. One well-known anatomist told me it was the eighth, and another that it was the sixteenth, of an inch. One dictionary declares that it is one-tenth, and another that it is the twelfth, of an inch. Would it not be well, with these facts in our mind, to adopt the metrical system, and have a standard of measurements affixed to the walls of every dissecting-room?

The Pterion in different Races of Men. By ARTHUR THOMSON, M.B. Edin., Reader in Human Anatomy, University of Oxford.

Mr THOMSON laid before the Society the results of his examination of this region in 413 skulls belonging to the Ethnological Collection in the University Museum at Oxford. By means of tracings, the method of obtaining which he described, he was able to demonstrate to the Society a persistency of type in certain races of the contours of the sutures around the pterion, the variations being due to alterations in the growth and development of the great sphenoidal wings and the squamous temporals. As perhaps the most marked examples of this fact, he cited the tracings of the Eskimo and Bushmen.

Mr Thomson then passed on to deal with the question of epipteric bones, and the occasional presence of a suture between the frontal and squamous temporal. In regard to the former he combated the view held by Sutton (*Jour. Anat. and Phys.*, vol. xviii.), that these epipteric bones were *always* present in the skulls of young persons under fifteen, and that their origin was due to a remnant of the cartilage of the orbito-sphenoid in the antero-lateral fontanelle.

His own observations lead him to believe that their origin did not differ from other Wormian bones, and in support of his view he stated that he had been unable to find any trace of cartilage in the antero-

lateral fontanelles in a number of fœtuses, some of which he showed to the Society.

The author, by a reference to the prevailing type of the races from which the skulls having these epipterics were taken, showed that for the most part they were to be looked upon as separated portions of the ali sphenoid or of the ant. inf. ang. process of the parietal, at the same time pointing out by numerous examples that in many cases at least the position of the epipteric ossicle was such that it could not be developed from the cartilage of the orbito-sphenoid. In addition, it was to be noticed that these epipterics were not unfrequently found in skulls in which Wormian bones were elsewhere found. Reference was also made to the difference in the fontanelles in children, and specimens were referred to in which little osseous nodules evidently of membrane origin were seen scattered throughout the fontanelle.

In conclusion, Mr Thomson said his observations with regard to some skulls differed widely from those of Mr Sutton.

Out of fifty skulls of young persons of fifteen and under belonging to the collection of the College of Surgeons only three skulls possessed epipterics on *both sides*, fourteen had epipterics on the *right side*, and six skulls display these bones on the *left side* only.

As the time was limited he only made a passing reference to the occasional occurrence of a suture between the frontal and squamoso-temporal. That he considered to be rather an accident, due in many cases to the fusion of a pre-existing epipteric bone with either the frontal or squamosal, as has been before shown, and he pointed out that in forty-one Australians and Tasmanians examined, races in which the pterion is narrow, the average width of the spheno-parietal articulation being only 6·1 mm., there did not occur a single instance of this abnormality, a fact which, he thought, went rather to prove that the occurrence of such a suture was more probably accidental than a reversion to a lower type.

Before concluding Mr Thomson said he should have liked to have referred in more detail to the racial difference, but time prevented.

Mr SUTTON said that he was delighted to find that Mr Thomson had satisfied himself, and also the meeting, that the piece of cartilage which runs along the posterior border of the orbito-sphenoid is as he described it. He was never positive in his opinion that the epipteric bone had its origin in cartilage, and had expressed an opinion somewhat reservedly on that point. He should like to know the ages of the skulls in which Mr Thomson had failed to find the epipteric bone, because it is very possible that, working on a limited number of skulls, he had fixed the date of fusion too late : also, in those cases in which no epipteric bone existed, if the skulls were also examined from within as well as from without. Frequently the suture was visible from the interior of the skull, when no trace could be seen from without.

Professor G. B. HOWES suggested that the development of the epipteric bone may have resulted from the increase in transverse diameter of the cranial roof, and pointed (in support of the supposition) to the duplication of the ossific centre in the expanded supra-

occipital of the Cetacea, and to the replacement under similar conditions of median by paired scutes, in the cranial roof of certain *Osteichthyes.* While supporting Mr Thomson's deductions, he deprecated the growing tendency towards attaching an important morphological value to secondary structures such as the one under consideration, and expressed the opinion that, in bringing the advocates of conflicting views face to face and fully discussing their differences, the Society was performing a work worthy of its institution and highest ambitions.

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